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Evaluation of Solidified Residue from Municipal Solid Waste Combustors

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16. ABSTRACT

This study was conducted to evaluate the effectiveness of commercial solidification techniques for immobilizing contaminants in municipal incinerator ash. Six different ash samples from five plants were used. None of the ash samples contained sufficient organics for detection, consequently such analyses were not conducted on the solidified samples. Inorganic analyses were made for thirteen metals, five of which were the most prevalent - they were calcium, copper, lead, sodium and zinc. Three solidification techniques were used, all showed significant containment potential.

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EVALUATION OF SOLIDIFIED RESIDUE FROM MUNICIPAL SOLID WASTE COMBUSTORS

by

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the water, wastewater, pesticides, toxic substances, solid and hazardous wastes, and Superfund-related activities. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Ash from municipal waste combustors is being generated in increasing quantities. Disposal of this waste and its impact on the environment remain uncertain. This research was undertaken to characterize ash from several incinerators and to determine if solidification can immobilize the ash constituents and prevent them from migrating to the environment. This report provides a better insight on the fate of waste constituents upon solidification, and help guide us in managing the waste properly and effectively.

E. Timothy Oppelt, Director
Risk Reduction Engineering Laboratory

ABSTRACT

This task was performed to evaluate the effectiveness of commercial solidification techniques for immobilizing inorganic and organic constituents in five municipal refuse incinerator ash (MRIA) samples. The ash samples were analyzed for selected organic and inorganic constituents. Organic compounds determined included: polychlorinated biphenyls, chlorinated phenols, polycyclic aromatics, polychlorinated dibenzo-p-dioxins, and polychlorinated dibenzofurans. The concentrations of these compounds in the ash samples were equal to or below the method detection limits. Thus, the organic characterization was deleted from the remaining analytical scheme.

The ash samples were also analyzed for elemental content, including arsenic, barium, boron, cadmium, calcium, chromium, copper, lead, mercury, nickel, selenium, sodium, and zinc. The most prevalent elements in the ash samples were calcium (2.2-8.8%), copper (0.04-0.17%), lead (0.07-0.17%), sodium (0.28-1.8%), and zinc (0.15-6.69%).

Toxicity Characteristic Leaching Procedure (TCLP) extracts were made from the unsolidified ash samples. Analysis of the TCLP extracts indicated that concentrations of metals in the ash were well below regulatory limits. The extracts of the Marion combined ash and Dayton fly ash contained the greatest concentrations of trace metals.

Three solidification techniques were performed on the ash samples: chemical fixation, cementation with kiln dust, and cementation with fly ash. The Dayton combined ash and fly ash samples were solidified by cementation techniques. All of the ash samples were solidified by the chemical fixation technique.

The TCLP and Static Leach Test (SLT) procedures were performed on solidified ash samples. Extracts generated from the Dayton fly ash and the Marion combined ash were analyzed for elemental content. Concentrations of all metals in the ash extracts were well below regulatory limits.

Because organic compounds were either not detected or were found in low ppb levels in the ash samples, these compounds were not determined in the TCLP extracts. The analytical results for TCLP and SLT extracts showed that outstretched metals were well below regulatory limits in all ash samples before and after the ash samples were solidified. Based on the results of this investigation, additional ash samples known to be relatively high in metals and organic compounds should be solidified and analyzed. Time averaged samples should be obtained which would give a more accurate representation of ash characteristics.

This report was submitted in fulfillment of contract #68-01-6999, task #59 by Radian Corporation under sponsorship of the U.S. Environmental Protection Agency. It covers a period from March 1, 1987 to September 30, 1987 and work was completed as of the latter date.

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SECTION 1

INTRODUCTION AND OBJECTIVES

This task was performed to evaluate the effectiveness of commercial solidification techniques for immobilizing TCLP-extractable hazardous constituents in municipal refuse incinerator ash (MRIA). Ash samples were collected from five municipal refuse incinerators. Combined ash samples, consisting of a mixture of bottom ash and fly ash, were collected from the five facilities. A sample of fly ash was collected from the facility at Dayton, Ohio, resulting in a total of six ash samples.

All ash samples were solidified by chemical fixation. Two of the ash samples, a combined ash and a fly ash, were also solidified by cementation with kiln dust and with fly ash.

Concentrations of inorganic constituents in the ash samples and their extracts were compared before and after the solidification procedures. The extracts of the ash samples were not analyzed for organic constituents because of the low organic compositions of the ash.

SECTION 2

METHODS

Ash samples were collected from five municipal refuse incineration facilities. The location of each facility and the type of solidification treatments applied to ash samples are summarized in Table 1. The scheme used for the analysis of the ash samples before and after solidification is illustrated in Figure 1.

2.1 ASH CHARACTERIZATION

The pH of the ash samples was determined by preparing a slurry consisting of equal volumes of sample and deionized water and measuring the pH of the decanted liquid as specified in the Methods of Soil Analysis of the American Society of Agronomy (ASA). A slurry of one part fly ash to five parts water was used to generate enough volume for pH analysis of the Dayton fly ash sample.

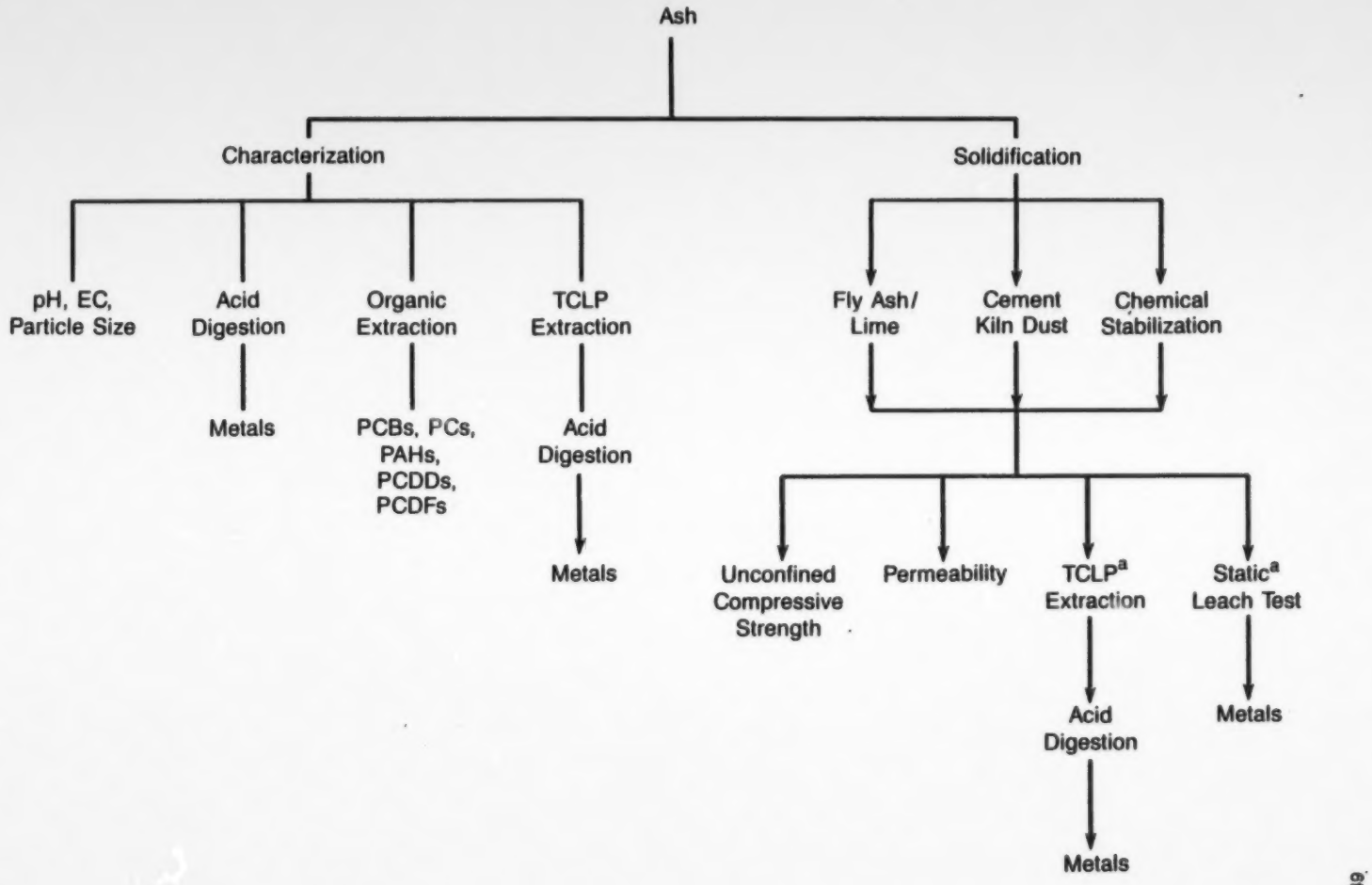
Electrical conductivity (EC) was determined on a slurry of ash and water mixed at a 1:1 ratio. The Dayton fly ash sample required a 1:5 ratio to provide enough slurry for conductivity determination.

The distribution of particle sizes in the ash samples was quantitatively determined using ASTM D 422-63. The distribution of particle sizes larger than 75 μm (retained on the No. 200 sieve) was determined by sieving, while the distribution of particle sizes smaller than 75 μm was determined by sedimentation with a hydrometer.

TABLE 1. SOLIDIFICATION TREATMENT OF MUNICIPAL INCINERATOR ASH COLLECTED FROM VARIOUS LOCATIONS

Location	Type of Ash	Type of Solidification
Pinellas, Florida	Combined	CF[a]
Westchester, New York	Combined	CF
Marion County, Oregon	Combined	CF
Pittsfield, Massachusetts	Combined	CF
Dayton, Ohio	Combined	CF,KD[b],FA[c]
	Fly Ash	CF,KD,FA

[a]Chemical Fixation.
[b]Cementation with Kiln Dust.
[c]Cementation with Fly Ash.



[a]TCLP and SLT extracts were generated in duplicate, for each of the solidified samples. Only the Marion combined ash and the Dayton fly ash extracts were analyzed.

Figure 1. Analytical scheme for evaluating municipal refuse incinerator ash.

2.1.1 Organic Analyses

Polynuclear aromatic hydrocarbons (PAHs) were determined in ash samples by HPLC using EPA Method 8310. Before analysis, samples were extracted according to EPA Method 3540. This method allows ppb (mg/Kg) levels of PAHs to be determined using high performance liquid chromatography (HPLC). A 5- to 25-μL aliquot of the extract was injected into an HPLC, and compounds in the effluent were detected by ultraviolet (UV) and fluorescence detectors.

Chlorinated phenols (CPs) were determined in the ash samples by gas chromatography (GC) using EPA Method 8040. The samples were extracted by EPA Method 3540. An aliquot of the extract was injected into the GC using the solvent flush technique. Compounds were detected with a flame ionization detector (FID).

Polychlorinated biphenyls (PCBs) in the ash sample were determined by GC using EPA Method 8080. The samples were extracted using EPA Method 3540. An aliquot of the extract was injected into the GC using the solvent flush technique. Compounds were detected with an electron capture detector (ECD) and were determined as Aroclor mixtures.

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were determined according to Method 8280. This procedure includes a matrix-specific extraction, analyte-specific cleanup, and high resolution capillary column gas chromatography/low resolution mass spectrometry (HRGC/MS) techniques. Parts per billion (mg/Kg) detection limits were obtained by this method.

2.1.2 Inorganic Analysis

Inductively coupled argon emission spectroscopy (ICP) was used to analyze for boron, barium, cadmium, calcium, chromium, copper, nickel, silver, sodium, and zinc in the ash and leachate samples. Before analysis, the ash and leachate samples were subjected to the acid digestion procedures listed in Table 2.

TABLE 2. ANALYTICAL METHODS

Parameter[a]	Ash		Leachate	
	Digestion/ Extraction	Analysis	Digestion/ Extraction	Analysis
Particle Size	NA	ASTM D 422[b]	NA	NA
pH	NA	ASA 12-2.6.5[c]	NA	NA
Conductivity	NA	ASA 10-3.3[c]	NA	NA
PCBs	3540[d]	8080[d]	NA	NA
CPs	3540[d]	8040[d]	NA	NA
PAHs	3540[d]	8310[d]	NA	NA
PCDD	8280[d]	8280[d]	NA	NA
PCDF	8280[d]	8280[d]	NA	NA
Ag, B, Ba, Ca Cd, Cr, Cu, Na, Ni, Zn	3050[d]	6010[d]	3010[d]	6010[d]
As	3050[d]	7060[d]	7060[d]	7060[d]
Se	3050[d]	7740[d]	7740[d]	7740[d]
Hg	7471[d]	7471[d]	7470[d]	7470[d]
Pb	3050[d]	7421[d]	3020[d]	7421[d]

[a]Unconfined compressive strength and permeability analyses were performed on the solidified samples.

[b]Annual Book of ASTM Standards, Philadelphia: American Society of Testing and Materials, 1986.

[c]Page, A.L., ed. Methods of Soil Analysis, Parta 2, Chemical and Microbiological Properties. 2nd ed. Madison: American Society of Agronomy, Inc. and Soil Science Society of America, Inc., 1982.

[d]Test Methods for Evaluating Solid Waste, Volume 1B: Laboratory Manual Physical/Chemical Methods. 3rd ed. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, SW-846, November 1986.

NA = Not applicable for the parameter.

The basis of chemical analysis by this method is the measurement of atomic emission by an optical spectroscopic technique. Samples were nebulized, and the aerosol produced was transported to the plasma torch where excitation occurred. Characteristic atomic-line emission spectra were produced by a radio frequency, inductively coupled plasma. The resulting spectra were dispersed by a grating spectrometer, and the intensities of the line were monitored by photomultiplier tubes. Plots of emission intensity versus concentration were established for each analyte using standard solutions. The concentration of each analyte in a sample was determined using the sample emission intensity and these standard plots. Background correction and interelement correction techniques were used for all analyses.

Furnace atomic absorption spectrophotometry was used to analyze samples for arsenic, lead, and selenium by the procedures outlined in EPA Methods 7060, 7421, and 7740, respectively. Before analysis, acid digestions of the samples were performed according to the digestion methods listed in Table 2.

Following acid digestion, an aliquot of sample was dried, charred, and atomized in a graphite furnace. Radiation from a light source, emitting spectral lines that are characteristic of the test element, was passed through the resulting vapor containing ground-state atoms. The decrease in the spectral intensity (as energy was absorbed in promoting ground state to excited state electrons) across the vapor was determined. A plot of absorbance versus standard concentration (Beer's Law) was used to determine the concentration of the analyte in sample digestates.

Cold vapor atomic absorption spectroscopy was used to determine mercury in the ash and leachate samples. Following acid digestion, as described in Methods 7470 and 7471, mercury was reduced to its elemental state with stannous sulfate. The mercuric vapor was then pumped through a closed system to a cell positioned in the light path of an atomic absorption spectrophotometer, and the amount of light absorbed was determined. A Beer's Law plot was used to determine the concentration of mercury in the sample.

2.2 ASH SOLIDIFICATION AND PHYSICAL ANALYSIS

2.2.1 Ash Solidification

The ash samples were passed through a sieve with 1.25-cm screen openings, homogenized, coned, and quartered to obtain one-gallon quantities. Samples were then shipped to each solidification vendor for processing.

The vendors prepared the solidified ash samples according to specifications in ASTM Method C-192-81 entitled, "Standard Method of Making and Curing Concrete Test Specimens in the Laboratory."

Chemfix Technologies, Inc. solidified all of the ash samples using a chemical fixation process in an enclosed system. Each ash sample was diluted 33-70% with water to make a slurry. A cement setting agent was added and mixed to produce a homogeneous mixture. The soluble setting agent was then added to the mixtures, which were poured into molds and allowed to cure for 24 to 48 hours. The solidified samples were shipped to Radian in their molds for testing.

Conversion Systems, Inc. solidified the Dayton combined ash and fly ash samples using cementation with kiln dust. A 1:1 ratio of cement kiln dust to sample was used. Water was added and the samples were compacted into their molds. The samples were then cured for seven days.

Conversion Systems, Inc. also solidified the Dayton fly ash and combined ash samples using cementation with fly ash. A 1:1 ratio of fly ash to sample was used. A five percent solution of lime and water was added to the mixtures, which were then compacted into molds and cured for seven days.

2.2.2 Physical Analysis

The unconfined compressive strength (UCS) of the solidified samples was measured. The UCS is defined as the load per unit area (psi) at which an

unconfined cylindrical sample of solids will fail in a compression test. Unconfined compressive strength measurement provide a method for estimating the maximum shear strength developed by solidified ash samples. They also provide data for assessing the feasibility of using these wastes for construction materials.

The permeability coefficients for cured solidified ash samples were measured using a flexible-wall membrane triaxial cell. Permeability coefficients express the linear rate of flow of a fluid through a material under a hydraulic gradient of unity. Permeability data can be used to estimate the amount of leachate flowing through solidified ash under a given set of conditions.

2.3 TOXICITY CHARACTERISTIC LEACHING PROCEDURE EXTRACTION AND STATIC LEACH TEST

2.3.1 Toxicity Characteristic Leaching Procedure

The ash and solidified ash samples were extracted according to the Toxicity Characteristic Leaching Procedure (TCLP) (TCLP, the Federal Register, Vol. 561, No. 114, p. 40643-40652). The TCLP is designed to assess the presence of organic and inorganic contaminants in liquid, solid, and multi-phase wastes.

The method calls for reducing the particle size of the samples by grinding so that they can pass through a 9.5-mm sieve. The extraction fluid employed is a function of the alkalinity of the solid phase waste as described in the TCLP, Step 7.12. The fly ash sample from Dayton, Ohio, was extracted with an acetate buffer with a pH of 2.88. All other ash and solidified samples were extracted with an acetate buffer with a pH of 4.94. The extraction fluid to sample ratio was 20:1. This mixture was mixed on an NBS tumbler for 18 hours and then filtered through a 0.60- to 0.80-μm glass-fiber filter to remove solids.

2.3.2 Modified Static Leach Test

Solidified ash samples were extracted by the static leach test (SLT) (MCC-IP Static Leach Test Method, 1983, provided by Materials Characterization Center). The static leach test measures the maximum credible concentrations of elements in quasi-static, ground water that has been in contact with a stabilized waste.

The weighed samples were immersed in distilled water and held at 40°C for 14 days. Extracts for analyses were collected after 7 and 14 days. Specimens of each solidified ash (sample surface area approximately 35 cm^2) were immersed without agitation in approximately 140 mL of distilled water at 40°C.

Sequential static leach tests were performed for each solidified ash sample. One set of extracts was collected after seven days. The other set of extracts was collected after 14 days. Each extract was filtered through a 0.60- to 0.80-μm glass-fiber filter to remove solids.

SECTION 3

RESULTS

This section presents the results of the analyses of the ash and solidified samples.

3.1 ASH CHARACTERIZATION

3.1.1 Physical Characterization

The results for EC and pH analyses performed on the municipal refuse incinerator ash (MRIA) samples are presented in Table 3. All of the MRIA samples were alkaline with pH values less than 12.5. The Dayton combined ash sample was the only MRIA with a pH less than 10. Electrical conductivities of the MRIA slurries ranged from 1650 μmhos/cm for the Dayton combined ash to approximately 28000 μmhos/cm for the Marion combined fly ash. The Marion combined ash and the Westchester combined ash had the largest conductivities (28,000 and 11,600 μmhos/cm), indicating a high concentration of soluble salts.

The particle size for each MRIA sample was determined using ASTM D 422. Average particle sizes for each ash sample, presented in Table 3, were determined from the particle size (Appendix A) distribution. The Dayton fly ash had the smallest mean particle size (0.055 mm), while the Pinellas combined ash had the largest mean particle size (7.0 mm).

3.1.2 Organic Characterization

Polynuclear aromatic hydrocarbons (PAHs) in the ash samples were determined by high pressure liquid chromatography (HPLC) using EPA Method 8310. These analytical results are shown in Table 4. The Westchester combined ash

TABLE 3. PHYSICAL PARAMETERS OF MUNICIPAL REFUSE INCINERATOR ASH (MRIA) SAMPLES

Location	Sample Type	pH	Conductivity (μmhos)	Mean Particle Size (mm)
Pinellas, FL	Combined Ash	12.12	6620	7.0
Westchester, NY	Combined Ash	11.72	11600	0.9
Marion, OR	Combined Ash	10.36	28100	3.0
Pittsfield, MA	Combined Ash	11.92	6200	6.0
Dayton, OH	Combined Ash	9.61	1650	2.0
Dayton, OH	Fly Ash	11.50[a]	6000[a]	0.05

[a]A one-part ash and five-part water slurry was needed to generate sufficient slurry volume for pH and conductivity analysis.

TABLE 4. POLYNUCLEAR AROMATIC HYDROCARBON RESULTS FOR MUNICIPAL REFUSE INCINERATOR ASH (MRIA) SAMPLES

Compound	Blank	Combined Ash Pinellas, FL	Combined Ash Westchester, NY	Combined Ash Marion, OR	Combined Ash Pittsfield, MA	Combined Ash Dayton, OH	Fly Ash Dayton, OH
		ug/kg					
Naphthalene	(7)[a]	18	36	25	23	56	42
Acenaphthylene	(125)	(125)	(125)	(125)	(125)	(125)	(125)
Acenaphthene	(3)	(3)	11	3.8	(3)	7.4	(3)
Fluorene	(2)	(2)	14	7.6	(2)	15	3.4
Phenanthrene	(6)	6.2	123	9.4	11	43	(6)
Anthracene	(4)	(4)	20	(4)	(4)	(4)	(4)
Fluoranthene	(4)	11	114	12	(4)	30	(4)
Pyrene	(12)	(12)	69	(12)	(12)	16	(12)
Benzo(a)anthracene	(2)	(2)	50	7.9	(2)	13	(2)
Chrysene	(6)	(6)	36	(6)	(6)	10	(6)
Benzo(e)pyrene	(6)	(6)	15	(6)	(6)	(6)	(6)
Benzo(b)flouranthene	(5)	(5)	29	(5)	(5)	8.8	(5)
Benzo(k)flouranthene	(1)	(1)	16	3.0	(1)	5.2	(1)
Benzo(a)pyrene	(1)	2.4	22	3.5	(1)	6.9	(1)
Diben(a,h)anthracene	(3)	(3)	5.2	(3)	(3)	(3)	(3)
Benzo(g,h,i)perylene	(7)	(7)	32	(7)	(7)	9.3	(7)

[a]Compound was not detected at the minimum detection limit given in parentheses.

sample contained the highest concentrations of PAHs. These compounds were all found at levels less than 125 ppb (μg/kg). Further analysis by gas chromatography/mass spectrometry (GC/MS) was not conducted because levels found in the GC screening phase were below the GC/MS detection limits.

Chlorinated phenols (CPs) in the ash samples were determined by GC using EPA Method 8040. These results appear in Table 5. Chlorinated phenols were either not detected or were within a factor of five times the detection limit in the MRIA samples.

Aroclors (polychlorinated biphenyls) in the ash samples were determined by GC using EPA Method 8080. Aroclors were not detected in any of the MRIA samples (see Table 6). The level of confidence in PCB identifications by Aroclor pattern recognition can be decreased for incinerator ash samples where PCB components of Aroclor mixtures degrade at different rates when incinerated. These samples were also analyzed by EPA Method 680 (Appendix C).

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) were determined by GC/MS using EPA Method 8280. PCDDs and PCDFs were not detected in any of the MRIA samples, as shown in Table 7. Surrogate recovery of the octachlorinated dibenzodioxin (OCDD) in the Dayton fly ash was outside the quality control limits. A second aliquot of this sample was spiked, extracted, and analyzed. Once again, the OCDD surrogate was not recovered, indicating that this compound was adsorbed by the fly ash and not extracted by this method.

Because of the very low levels of organics found in these MRIA samples, organic characterization of the ash leachates, the solidified ashes, and the leachates of the solidified ashes was deleted from the experimental scheme.

TABLE 5. CHLORINATED PHENOLS IN MUNICIPAL REFUSE INCINERATOR ASH (MRIA) SAMPLES

Compound	Blank	Combined Ash Pinellas, FL	Combined Ash Westchester, NY	Combined Ash Marion, OR	Combined Ash Pittsfield, MA	Combined Ash Dayton, OH	Fly Ash Dayton, OH
		mg/kg					
Phenol	(0.30)[a]	(0.30)	(0.29)	(0.33)	(0.32)	0.45	(1.1)
2-Chlorophenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
2-Nitrophenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	2.9
2,4-Dimethylphenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
2,4-Dichlorophenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
4-Chloro-3-m-phenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
2,4,6-Trichlorophenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
2,4-Dinitrophenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
4-Nitrophenol	(0.60)	(0.60)	(0.57)	(0.66)	(0.64)	(0.66)	(12.2)
Methyl-4,6-dinitrophenol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
Pentachlorophenol	(0.60)	(0.60)	(0.57)	(0.66)	(0.64)	(0.66)	(12.2)
o-Cresol	(0.30)	(0.30)	(0.29)	(0.33)	(0.32)	(0.33)	(1.1)
p-Cresol	(0.30)	(0.30)	0.85	0.39	0.32	0.39	1.7

[a]Compound was not detected in the sample at the minimum detection limit listed in parentheses.

TABLE 6. CONCENTRATION OF AROCLORS IN MUNICIPAL REFUSE INCINERATOR ASH (MRIA) SAMPLES

Compound	Blank	Combined Ash Pinellas, FL	Combined Ash Westchester, NY	Combined Ash Marion, OR[a]	Combined Ash Pittsfield, MA[b]	Combined Ash Dayton, OH[c]	Fly Ash Dayton, OH
		mg/kg					
Aroclor 1221	(0.050)[d]	(0.050)	(0.050)	(5.0)	(0.75)	(0.50)	(0.050)
Aroclor 1232	(0.050)	(0.050)	(0.050)	(5.0)	(0.75)	(0.50)	(0.050)
Aroclor 1242	(0.040)	(0.040)	(0.040)	(4.0)	(0.60)	(0.40)	(0.040)
Aroclor 1248	(0.025)	(0.025)	(0.025)	(2.5)	(0.38)	(0.25)	(0.025)
Aroclor 1253	(0.025)	(0.025)	(0.025)	(2.5)	(0.38)	(0.25)	(0.025)
Aroclor 1260	(0.025)	(0.025)	(0.025)	(2.5)	(0.38)	(0.25)	(0.025)

[a] Sample extract diluted 1:100 due to interferences.
[b] Sample extract diluted 1:15 due to interferences.
[c] Sample extract diluted 1:10 due to interferences.
[d] Compound in the sample was not detected at the minimum detection limit shown in parentheses.

TABLE 7. POLYCHLORINATED DIBENZO-p-DIOXINS AND DIBENZOFURANS IN MUNICIPAL REFUSE INCINERATOR ASH (MRIA) SAMPLES

Compound[a]	Combined Ash Pinellas, FL	Combined Ash Westchester, NY	Combined Ash Marion, OR	Combined Ash Pittsfield, MA	Combined Ash Dayton, OH	Fly Ash Dayton, OH
	ug/kg					
2,3,7,8 - TCDD	(0.22)[b]	(0.20)	(0.21)	(0.22)	(0.32)	(0.28)
Total TCDD	(0.22)	(0.20)	(0.21)	(0.22)	(0.32)	(0.28)
Total TCDF	(0.15)	(0.14)	(0.14)	(0.15)	(0.16)	(0.16)
Total PeCDD	(0.24)	(0.21)	(0.22)	(0.26)	(0.25)	(0.38)
Total PeCDF	(0.22)	(0.18)	(0.19)	(0.23)	(0.22)	(0.31)
Total HxCDD	(0.49)	(0.38)	(0.37)	(0.47)	(0.48)	(0.93)
Total HxCDF	(0.70)	(0.36)	(0.39)	(0.68)	(0.55)	(0.63)
Total HpCDD	(0.60)	(1.03)	(0.44)	(0.53)	(0.65)	(2.93)
Total HpCDF	(0.78)	(1.09)	(0.39)	(0.69)	(0.65)	(1.92)
Total OCDD	(0.86)	(1.74)	(0.65)	(0.61)	(0.81)	ND
Total OCDF	(0.70)	(0.48)	(0.41)	(0.55)	(0.74)	(2.94)

[a]Analytes are various chlorinated dibenzodioxins (*CDD) or chlorinated dibenzofurans (*CDF) based upon the number of chlorine atoms attached to the respective molecule where: T = tetra, Pe = penta, Hx = hexa, HP = hepta, and O = octa.
[b]Sample concentration was less than the minimum detection limit listed in parentheses.

ND - Not detected, surrogate not recovered.

3.1.3 Inorganic Characterization

Inductively coupled plasma emission spectroscopy (ICP) was used to analyze for boron, barium, cadmium, calcium, chromium, copper, nickel, silver, and zinc. Arsenic, selenium, lead, and mercury were analyzed by atomic absorption spectroscopy (AAS). The results for the determination of trace elements in MRIA samples are shown in Table 8. The most prevalent inorganic species were calcium (2.2 to 8.8%), copper (0.04 to 0.17%), lead (0.07 to 0.17%), sodium (0.28 to 1.8%), and zinc (0.15 to 0.69%).

3.1.4 Toxicity Characteristic Leaching Procedure

Ash samples were extracted according to the Toxicity Characteristic Leaching Procedure (TCLP). The method was designed to simulate leaching of organic and inorganic contaminants from waste when it is codisposed with municipal wastes in a sanitary landfill. The purpose of the method is to determine if a waste is a potential hazard to human health or the environment.

The resultant extracts were characterized for inorganic constituents. These results appear in Table 9. Metal concentrations were below the regulatory levels defined in the TCLP for all ash samples analyzed. The low levels of trace elements found in the TCLP extracts indicated that the metals in the MRIA samples were not soluble in the extraction fluid. The TCLP extracts of the Marion combined ash and the Dayton fly ash contained the largest concentrations of metals; therefore, only the leachates of these two solidified samples were submitted for inorganic analyses.

3.2 SOLIDIFIED SAMPLES

3.2.1 Physical Characterization

Permeability coefficients were measured on the solidified, cured waste materials using a flexible-wall membrane triaxial cell. Permeability

TABLE 8. ELEMENTAL CONCENTRATIONS IN MUNICIPAL REFUSE INCINERATOR ASH (MRIA) SAMPLES[a]

Analyte	Blank	Combined Ash Pinellas, FL	Combined Ash Westchester, NY	Combined Ash Marion, OR	Combined Ash Pittsfield, MA	Combined Ash Dayton, OH	Fly Ash Dayton, OH
		mg/kg					
Arsenic	(0.2)[b]	15	30	23	26	23	49
Barium	(0.9)	280	520	270	340	320	1200
Boron	(57)	(230)	90	60	(57)	(60)	280
Cadmium	(1.2)	16	82	44	18	9	22
Calcium	390	43000	49000	62000	22000	26000	88000
Chromium	(3.9)	55	75	47	63	47	160
Copper	(4.0)	1600	3500	450	5500	1650	530
Lead	(0.2)	730	2900	1700	1700	1600	790
Mercury	(0.05)	0.24	7.3	17	0.41	0.29	(0.05)
Nickel	(2.0)	55	120	90	33	235	230
Selenium	(0.5)	(0.5)	1.6	0.6	(0.5)	(1.0)	(0.01)
Silver	(0.9)	5	21	10	4	1	8
Sodium	720	3000	11000	8900	3400	2750	18000
Zinc	(2.4)	1500	6600	6900	2400	1500	1400
% Moisture	(0.1)	11.4	4.4	17.6	44.2	27.0	(0.1)

[a]Method detection limits varied because samples were diluted if matrix interferences or high total dissolved solids were encountered.
[b]Concentration of analyte in the sample is less than the minimum detection limit listed in parentheses.

TABLE 9. ELEMENTAL CONCENTRATIONS IN THE TCLP EXTRACTS OF THE MUNICIPAL REFUSE INCINERATOR ASH (MRIA) SAMPLES[a]

Analyte	Blank	Combined Ash Pinellas, FL	Combined Ash Westchester, NY	Combined Ash Marion, OR	Combined Ash Pittsfield, MA	Combined Ash Dayton, OH	Fly Ash Dayton, OH
		mg/kg					
Arsenic	(0.004)[b]	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	0.092
Barium	0.011	0.10	0.18	0.23	0.22	0.21	0.59
Boron	(0.6)	(0.6)	1.0	0.9	0.9	(0.6)	7.1
Cadmium	0.003	0.008	0.008	0.022	0.014	0.005	0.042
Calcium	0.24	455	570	860	420	460	1400
Chromium	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	1.5
Copper	(0.01)	0.13	(0.01)	0.54	(0.01)	(0.01)	0.04
Lead	0.017	0.005	0.005	0.011	0.027	0.031	0.014
Mercury	(0.0002)	(0.0002)	(0.0002)	0.009	(0.0002)	(0.0002)	(0.0002)
Nickel	(0.02)	(0.02)	(0.02)	(0.02)	0.05	1.0	0.25
Selenium	0.006	0.015	0.030	0.019	0.011	0.01	(0.003)
Silver	(0.009)	(0.009)	(0.009)	0.017	(0.009)	(0.009)	0.021
Sodium	1233	1300	1400	1300	1300	1100	36
Zinc	0.010	(0.006)	(0.006)	(0.023)	0.10	2.7	2.4

[a]Average of the analysis of four blank solutions.
[b]Concentration of analyte in the sample is less than the minimum detection limit listed in parentheses.

coefficients ranged from 8.7×10^{-5} to 1.4×10^{-6} cm/sec as shown in Table 10. For comparison, very fine sands, silts, and sand/silt/clay mixtures have permeability coefficients in the range of 10^{-4} to 10^{-7} cm/sec. In guidelines identifying and describing available solid waste management practices, the Environmental Protection Agency has described low permeability liner materials as those with permeability coefficients equal to or less than 1×10^{-7} cm/sec. Impervious clay has a permeability of approximately 10^{-9} cm/sec.

Unconfined compressive strength was measured in samples that were compacted and cured according to ASTM D 2166. Unconfined compressive strength results are presented in Table 10. Strengths ranged from 18 psi in the Marion combined ash solidified by chemical stabilization to 97 psi in the Dayton combined ash solidified by cementation with kiln dust. For materials to be disposed of in a landfill, minimum strengths of 50 psi or greater are desired.

3.2.2 Toxicity Characteristic Leaching Procedure

The solidified ash samples were extracted in duplicate using the Toxicity Characteristic Leaching Procedure (TCLP). Inorganic characterization was performed only on the extracts of the solidified Marion combined ash and Dayton fly ash. These results are presented in Tables 11 and 12. These extracts all contained concentrations below the regulatory levels defined in the TCLP. The TCLP extract of the Marion combined ash solidified by chemical fixation contained less barium, boron, cadmium, copper, mercury, and lead than the TCLP extract of the original ash. When corrected for sample dilution with solidification reagents, only cadmium, mercury and lead exhibit real decreases in concentrations. The TCLP extract of the Dayton fly ash sample solidified by chemical stabilization exhibited a decrease in arsenic, barium, boron, cadmium, chromium, lead, nickel, and zinc when compared with the TCLP extract of the original ash. When corrected for reagent dilution in the solidified ash, only boron, nickel, and zinc show a real reduction in concentration when compared to the raw ash.

TABLE 10. PERMEABILITY COEFFICIENTS AND UNCONFINED COMPRESSIVE STRENGTHS OF SOLIDIFIED MUNICIPAL REFUSE INCINERATOR ASH (MRIA)

Solidification Process	Location	Type of Ash	Permeability Coefficient (cm/sec)	Stress (psi)
Chemfix	Pinellas, FL	Combined Ash	1.4×10^{-6}	20.55
	Westchester, NY	Combined Ash	6.6×10^{-6}	87.46
	Marion, OR	Combined Ash	6.5×10^{-6}	18.10
	Pittsfield, MA	Combined Ash	1.0×10^{-5}	32.41
	Dayton, OH	Combined Ash	2.0×10^{-5}	35.78
	Dayton, OH	Fly Ash	3.4×10^{-5}	37.10
Kiln Dust	Dayton, OH	Combined Ash	4.2×10^{-6}	97.03
	Dayton, OH	Fly Ash	4.0×10^{-5}	21.43
Fly Ash	Dayton, OH	Combined Ash	2.0×10^{-6}	68.77
	Dayton, OH	Fly Ash	8.7×10^{-5}	37.86

TABLE 11. COMPARISON OF THE ELEMENTAL CONCENTRATIONS FOUND IN TCLP EXTRACTS OF MARION, OR, COMBINED ASH BEFORE AND AFTER SOLIDIFICATION

Analyte	Before Solidification mg/L	After Solidification[a] mg/L
Arsenic	0.004	0.013
Barium	0.23	0.18
Boron	0.9	0.6
Cadmium	0.022	0.006
Calcium	860	1850
Chromium	0.009	0.057
Copper	0.54	0.28
Lead	0.011	0.002
Mercury	0.009	0.001
Nickel	0.02	0.04
Selenium	0.019	0.015
Silver	0.017	0.024
Sodium	1300	245
Zinc	0.023	0.034

[a]Chemical fixation by Chemfix Technologies.

TABLE 12. COMPARISON OF THE CHEMICAL CONCENTRATIONS FOUND IN THE TCLP EXTRACTS OF DAYTON FLY ASH BEFORE AND AFTER SOLIDIFICATION

Analyte	Before Solidification	Chemical Fixation[a]	Kiln Dust[b]	Fly Ash[c]
	----------mg/L----------			
Arsenic	0.092	0.0004	0.004	0.01
Barium	0.59	0.4	0.44	0.45
Boron	7.1	(0.6)[d]	3.5	7.15
Cadmium	0.042	0.004	0.033	0.032
Calcium	1400	1350	2200	1550
Chromium	1.5	0.65	0.94	1.2
Copper	0.04	(0.01)	0.07	0.03
Lead	0.014	0.003	0.03	0.007
Mercury	(0.0002)	(0.0002)	0.0002	(0.0002)
Nickel	0.25	(0.02)	0.18	0.12
Selenium	(0.003)	(0.015)	(0.015)	(0.015)
Silver	0.021	0.018	0.036	0.028
Sodium	36	180	50	52
Zinc	2.4	0.03	2.2	1.2

[a]Chemical fixation by Chemfix Technologies.
[b]Cementation with kiln dust by Conversion Systems.
[c]Cementation with fly ash by Conversion Systems.
[d]The concentration of the analyte in the sample is less than the minimum detection limit listed in parentheses.

The TCLP extracts of the Dayton fly ash sample solidified by cementation with kiln dust (corrected for reagent dilution) contained lower concentrations of arsenic than the original ash.

The TCLP extracts of the Dayton fly ash solidified by cementation with fly ash (when corrected for solidification reagent dilution) exhibited lower concentrations in arsenic than did the TCLP extracts of the original ash.

3.2.3 Static Leach Test

Aliquots of the solidified samples were extracted by the Modified Static Leach Test (SLT). Two extracts (7 day and 14 day) were generated for each sample. Inorganic characterization was performed on the extracts of the solidified Marion combined ash and the Dayton fly ash. These results appear in Table 13.

The elemental concentration of the SLT extracts were similar for each of the three solidification techniques performed in the Dayton fly ash sample. The SLT extract of the sample solidified by cementation with kiln dust contained the highest concentrations of barium, chromium, and lead.

TABLE 13. ELEMENTAL CONCENTRATIONS IN SLT EXTRACTS OF THE SOLIDIFIED MUNICIPAL REFUSE INCINERATION ASH (MRIA) SAMPLES

Analyte	Blank		Chemical Fixation				Kiln Dust		Fly Ash	
			Combined Ash - Marion, OR		Fly Ash - Dayton, OH		Fly Ash - Dayton, OH		Fly Ash - Dayton, OH	
	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day	7 day	14 day
	mg/L									
Arsenic	(0.002)[a]	(0.002)	(0.002)	(0.008)	0.050	0.055	0.015	0.032	0.076	0.072
Barium	0.024	(0.009)	1.20	1.30	0.033	0.025	1.1	0.077	0.13	0.15
Boron	(0.6)	(0.6)	(0.6)	(0.6)	1.5	1.7	0.70	(0.6)	1.3	1.40
Cadmium	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Calcium	0.15	0.070	490	390	16	15	24	27	42	28
Chromium	(0.009)	(0.009)	0.033	0.028	2.9	3.8	3.6	3.2	0.37	0.92
Copper	0.01	(0.01)	1.20	1.30	0.03	0.02	0.04	0.03	0.01	(0.01)
Lead	(0.002)	(0.002)	0.16	0.480	0.093	0.036	0.10	0.080	0.026	0.056
Mercury	(0.0002)	0.0003	(0.0002)	0.0004	(0.0002)	0.0002	(0.0002)	0.0002	(0.0002)	(0.0002)
Nickel	(0.02)	(0.02)	0.05	0.05	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Selenium	(0.003)	(0.003)	(0.003)	(0.2)	(0.003)	(0.015)	(0.003)	(0.015)	(0.003)	(0.015)
Silver	0.009	(0.009)	0.028	0.012	(0.009)	(0.009)	0.016	(0.009)	0.014	(0.009)
Sodium	0.49	(0.08)	2300	2100	1200	1200	410	500	590	500
Zinc	0.009	0.024	0.046	0.024	0.033	0.037	0.036	0.041	0.1	0.036

[a]Concentration of analyte in the sample is less than the minimum detection limit listed in parentheses.

SECTION 4

QUALITY CONTROL

Quality control (QC) associated with this project included specific activities intended to ensure reliable analytical performance and to obtain data of known quality. The objectives of the QC efforts were to: 1) provide a mechanism for controlling analytical performance within acceptable limit, and 2) form a basis for defining limits of uncertainty associated with the measurement data. The control aspect of the QC effort consisted of numerous procedures designed to provide ongoing checks of the primary components of the various measurement processes. The evaluative aspect of the QC effort was designed to provide a basis for quantitative estimates of uncertainty associated with sample analysis.

Table 14 summarizes data quality estimates for sample analysis. These data provide information pertaining to two key aspects of measurement quality: precision and accuracy. Precision is an estimate of agreement among repeated measurements of the same sample. Accuracy is an estimate of agreement between measured values and true values. Precision estimates are based on the analysis of duplicate samples, while accuracy estimates are based on analysis of standard samples. A discussion of data quality for each of the parameter groups in Table 14 appears in the following sections.

4.1 METALS ANALYSES

Concentrations of selected metals in unsolidified ash samples and TCLP extracts of unsolidified and solidified ash samples were determined by inductively coupled plasma emission spectroscopy (ICPES) and atomic absorption spectroscopy (AAS). The analytical instruments were calibrated according to SW-846 Method 6010 (ICPES) and 7000 series (AAS) protocols. Analytical quality control measures included analysis of QC calibration (QCCS) and audit

TABLE 14. SUMMARY OF RECOVERY AND PRECISION DATA

Parameter	Percent Recovery[a]	Precision RPD[b]
Metals		
Ash	14 - 2000	23 - 190[c]
Extracts	23 - 106	7 - 78[d]
Organics		
PAHs	71 - 82	5 - 96[e]
PCBs	50	NC
Chlorinated Phenols	31 - 55	22[f]
Other phenols	0 - 90	13[f]
PCDDs/PCDFs	52 - 95	7 - 47[g]

[a] Range of mean matrix spike recoveries.
[b] Relative percent difference (RPD) for duplicate sample results, unless otherwise noted.
[c] PRD for matrix spike duplicates.
[d] RPD for duplicate extracts of untreated and solidified ash.
[e] RPD for duplicate ash samples.
[f] RPD based on one compound.
[g] Coefficient for eight surrogate spike recoveries.

NC - Not calculable. All results less than detection limit.

samples, contamination checks (blanks), replicate analyses, and spiked sample recoveries. Results for these samples are discussed below.

4.1.1 QCCS and Audit Samples

Following calibration, QC calibration samples, consisting of independently prepared calibration solutions in deionized water, were analyzed at a 10% frequency to verify ongoing calibration accuracy. Audit samples consisted of standard metal solutions spiked into TCLP and SLT extraction fluids. The QC calibration samples were analyzed without digestion, while audit samples were treated in the same way as TCLP and SLT extracts. The QCCS results are summarized in Table 15. Audit sample results are summarized in Table 16 for TCLP samples and in Table 17 for SLT samples.

The mean QCCS recovery for 14 metals ranged from 99 to 104%, which was within the recovery objective of 90 to 110% (Table 15). Repeatability of QCCS results was also good, ranging from 3.7 to 5.6% coefficient of variation (CV) for the 14 metals. These results indicate that the analytical systems for metals analyses were in control.

Audit samples for the TCLP extraction fluid consisted of two solutions with metals concentrations differing by an order of magnitude (Table 16). The silver concentrations in these audit samples were questionable due to the presence of hydrochloric acid in one of the standards used to make the the audit samples. The results for silver are not included in the following discussion of agreement between audit and TCLP or SLT samples. Percent agreement between the reported and audit values for the TCLP samples ranged from 33 to 163% in the low-level (Sample 1) sample and from 90 to 130% in the high-level (Sample 2) sample. Average agreements were 100$\pm$30% for 13 metals in the low-level audit sample and 90$\pm$26% in the high-level audit sample.

TABLE 15. SUMMARY OF QC CALIBRATION SAMPLE RESULTS FOR METALS

Parameter	Number of Analyses	Percent Recovery	Coefficient of Variation (Percent)
AAS			
Arsenic	20	98	5.6
Mercury	15	104	4.4
Lead	19	102	5.5
Selenium	23	99	5.5
ICPES			
Barium	19	101	3.7
Boron	15	101	3.8
Cadmium	19	102	4.8
Calcium	15	100	4.3
Chromium	19	101	3.7
Copper	19	100	4.0
Nickel	17	101	3.9
Silver	18	102	3.9
Sodium	15	103	3.7
Zinc	19	103	4.9

TABLE 16. PERFORMANCE AUDIT RESULTS FOR METALS IN TCLP EXTRACTS

Parameter	Minimum Detection Limit[a] (mg/L)	Expected Range of Agreement[b] (%)	Sample 1			Sample 2		
			Audit Value (mg/L)	Reported Value (mg/L)	Agreement[c] (%)	Audit Value (mg/L)	Reported Value (mg/L)	Agreement[c] (%)
Arsenic	0.002	77-119	0.03	0.027	90	0.3	0.27	90
Barium	0.009	83-121	1.0	0.96	96	10.0	9.5	95
Boron	0.6	--	2.0	1.9[d]	95	20.0	19	95
Cadmium	0.003	71-119	0.04	0.037	93	0.4	0.36	90
Calcium	0.06	--	0.43	0.49	114	4.3	3.9	91
Chromium	0.009	84-116	0.08	0.073	91	0.8	0.73	91
Copper	0.01	--	0.03	0.01	33	0.3	0.27	90
Lead	0.002	82-117	0.08	0.074	93	0.8	0.78	98
Mercury	0.0002	--	0.002	0.0025	125	0.02	0.026	130
Nickel	0.02	--	0.03	0.03	100	0.3	0.27	90
Selenium	0.005	62-124	0.03	0.038	126	0.3	0.31	103
Silver[d]	0.009	79-119	0.05[d]	0.04	80	0.5[d]	0.066	13
Zinc	0.006	--	0.03	0.049	163	0.3	0.3	100

[a]Minimum detection limit obtained for the TCLP matrix.
[b]Expected range of agreement based on EPA interlaboratory testing; the Austin Production Chemistry standard operating procedure accuracy objectives are ±10% for ICPES analyses.

[c]$\text{Agreement (\%)} = \frac{\text{Reported Value}}{\text{Audit Value}} \times 100$.

[d]Audit values for silver questionable due to the presence of HCl in a standard used to generate the audit samples.

TABLE 17. PERFORMANCE AUDIT RESULTS FOR METALS IN SLT EXTRACTS

Parameter	Minimum Detection Limit[a] (mg/L)	Expected Range of Agreement[b] (%)	Sample 1			Sample 2			Sample 3		
			Audit Value (mg/L)	Reported Value (mg/L)	Sample Recovery[c] (%)	Audit Value (mg/L)	Reported Value (mg/L)	Sample Recovery[c] (%)	Audit Value (mg/L)	Reported Value (mg/L)	Sample Recovery[c] (%)
Arsenic	0.002	77-119	0.03	0.03	100	0.3	0.27	90	0.15	0.13	86
Barium	0.009	83-121	1.0	0.95	95	10.0	9.8	98	5	5.1	102
Boron	0.6	--	2.0	2.0	100	20.0	20	100	10	10	100
Cadmium	0.003	71-119	0.04	0.035	88	0.4	0.36	90	0.2	0.19	95
Calcium	0.06	--	0.43	0.48	112	4.3	4.3	100	2.2	2.2	100
Chromium	0.009	84-116	0.08	0.076	95	0.8	0.76	95	0.4	0.39	98
Copper	0.01	--	0.03	0.03	100	0.3	0.3	100	0.15	0.15	100
Lead	0.002	82-117	0.08	0.088	110	0.8	0.9	113	0.4	0.42	105
Mercury	0.0002	--	0.002	0.017	85	0.02	0.024	120	0.01	0.0095	95
Nickel	0.02	--	0.03	0.03	100	0.3	0.29	97	0.15	0.15	100
Selenium	0.005	62-124	0.03	0.024	80	0.3	0.28	93	0.15	0.15	100
Silver[d]	0.009	79-119	0.05[d]	0.066	132	0.5[d]	0.081	16	0.25[d]	0.066	26
Zinc	0.006	--	0.03	0.023	76	0.3	0.3	100	0.15	0.16	107

[a] Minimum detection limit obtained for the SLT matrix.

[b] Expected range of agreement based on EPA interlaboratory testing; the Austin Production Chemistry standard operating procedure accuracy objectives are ±10% for ICPES analyses.

[c] $\text{Agreement (\%)} = \frac{\text{Reported value}}{\text{Audit Value}} \times 100.$

[d] Audit values for silver are questionable due to the presence of HCl in a standard used to generate the audit samples.

Three SLT extraction fluid audit samples were prepared and analyzed. Two of these samples contained metals concentrations identical to those of the TCLP audit samples. A third SLT audit sample was prepared to have a metals concentration of one-half that of the high-level sample. Recoveries ranged from 76 to 112% in the low-level sample, from 90 to 120% in the high-level sample, land from 86 to 107% in the mid-level sample.

4.1.2 Blank Samples

Table 18 summarizes results from the analysis of blank samples. Reagent blank samples were submitted with each type of sample analyzed for metals, including TCLP extraction fluids "one" (acetic acid) and "two" (sodium acetate), SLT 7- and 14-day extraction fluids (deionized water), and digestion solution for ash samples. The blank samples were processed as normal samples. In addition to calcium and sodium, which are expected at detectable levels in background samples, levels of barium, lead, and zinc were detected at concentrations well above the detection limits.

4.1.3 Duplicate Samples

Table 19 summarizes the precision estimates for duplicate TCLP extracts analyzed for metals. Duplicate unsolidified and solidified ash samples were extracted using the TCLP. Results for metals analyses in the duplicate samples provide a measure of overall precision, which includes variability associated with sample homogeneity, preparation and analysis. The relative percent difference (RPD) between duplicate samples ranged from 8 to 77% for 14 metals in (unsolidified) ash TCLP extracts and from 7 to 78% in solidified extracts. The average RPD was 36% for the unsolidified ash extracts and 35% for extracts of the solidified ash.

TABLE 18. SUMMARY OF BLANK SAMPLE RESULTS FOR METALS ANALYSIS

Parameter	Minimum Detection Limit (mg/L)	TCLP-2[a] (mg/L)	TCLP-1[b] (mg/L)	SLT-7[c] (mg/L)	SLT-14[d] (mg/L)	ASH[e] (mg/Kg)[f]
Arsenic	0.002	ND	ND	ND	ND	ND
Barium	0.009	0.23	0.011	0.024	ND	ND
Boron	0.6	ND	ND	ND	ND	ND
Cadmium	0.003	0.003	0.003	ND	ND	ND
Calcium	0.06	0.70	0.24	0.15	0.07	390
Chromium	0.009	0.018	ND	ND	ND	ND
Copper	0.01	0.02	ND	0.01	ND	ND
Lead	0.002	0.009	0.017	ND	ND	ND
Mercury	0.0002	0.0002	ND	ND	0.0003	ND
Nickel	0.02	ND	ND	ND	ND	ND
Selenium	0.015	ND	0.006	ND	ND	ND
Silver	0.009	ND	ND	0.009	ND	ND
Sodium	0.08	1.9	1233	0.49	ND	720
Zinc	0.006	0.20	0.010	0.009	0.024	ND

[a] TCLP extraction fluid 2 (sodium acetate buffer).
[b] TCLP extraction fluid 1 (acetic acid).
[c] SLT extraction (deionized water) 7 days.
[d] SLT extraction (deionized water) 14 days.
[e] Reagent blank digested with ash samples.
[f] Value reflects measured blank value (mg/L) times the ratio (100 L/Kg) of digestate volume (100 mL) to sample mass (1 g) used for ash samples. The detection limit for ash samples is thus 100 times that for aqueous samples.

TABLE 19. SUMMARY OF PRECISION ESTIMATES FOR DUPLICATE TCLP EXTRACTS ANALYZED FOR METALS

Parameter	Unsolidified Ash		Solidified Ash	
	No. of Pairs[a]	TCLP (Mean RPD[b])	No. of Pairs[a]	TCLP (Mean RPD[b])
Arsenic	1	17.4	4	32.7
Barium	6	25.5	4	53.9
Boron	4	13.8	2	10.5
Cadmium	5	54.9	4	38.0
Calcium	6	10.5	4	8.0
Chromium	2	11.9	4	12.0
Copper	3	28.4	3	24.1
Lead	6	72.3	4	69.7
Mercury	1	56.7	2	68.4
Nickel	3	61.9	3	43.2
Selenium	5	28.3	0	NC
Silver	3	40.5	4	7.2
Sodium	6	7.8	4	9.1
Zinc	4	76.7	4	77.7

[a]Number of duplicate sample pairs with results greater than the detection limit. RPD is not calculable when both results for a pair are "not detected."

[b]RPD Relative percent difference.

4.1.4 Matrix Spike/Matrix Spike Duplicates

Results for matrix spike/matrix spike duplicate (MS/MSD) analyses are summarized in Table 20. Additional data, including results for analytical spikes (i.e., spikes added after digestion) and method spikes (lab blanks spiked before digestion) appear in Appendix B. Matrix spike recovery data indicate acceptable recovery in the sample matrices for all metals except selenium. For matrix spikes, three aliquots were taken--one was analyzed unspiked, and the other two were spiked and analyzed.

4.2 ORGANIC ANALYSIS

Unsolidified ash samples were analyzed for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorinated phenols (PCs), and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDDs and PCDFs). No significant levels of organics were reported in the ash samples, although ppb levels of certain PAHs and PCs were detected. Precision and recovery estimates based on duplicate and spiked sample results are discussed below.

4.2.1 Duplicate Samples

A summary of precision estimates for duplicate ash samples analyzed for organics is presented in Table 21. This table shows the mean measured concentration for duplicate sample analyses and the relative percent difference between the duplicate results.

Polycyclic Aromatic Hydrocarbons--

Results were reported for twelve PAHs in duplicate ash samples. The mean measured concentrations ranged from 9 to 56 μg/Kg. The RPD between duplicate sample results ranged from 4 to 100 percent. The average RPD for the twelve pairs of duplicate results was 55 percent.

TABLE 20. MATRIX SPIKE/MATRIX SPIKE DUPLICATE RESULTS FOR METALS ANALYSES

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Arsenic	001	None	TCLP	<0.004	0.032	0.040	80	MS
	001	None	TCLP	<0.004	0.031	0.040	78	MSD
	007	None	TCLP	0.100	0.120	0.040	50	MS
	007	None	TCLP	0.100	0.120	0.040	50	MSD
	002	None	Ash	30	34	4.0	100	MS
	002	None	Ash	30	36	4.0	158	MSD
	003	Chemfix	TCLP	0.015	0.031	0.020	80	MS
	003	Chemfix	TCLP	0.015	0.031	0.020	80	MSD
	007	Kiln dust	TCLP	0.004[a]	0.02	0.020	80	MS
	007	Kiln dust	TCLP	0.004[a]	0.021	0.020	85	MSD
Mean							84	
RSD (%)							36	
Barium	003	None	TCLP	0.21	1.95	2.0	87	MS
	003	None	TCLP	0.21	1.93	2.0	86	MSD
	007	None	TCLP	0.56	2.4	2.0	92	MS
	007	None	TCLP	0.56	2.3	2.0	87	MSD
	002	None	Ash	520	580	200	30	MS
	002	None	Ash	520	700	200	90	MSD
	002	Chemfix	TCLP	0.17	1.09	1.0	92	MS
	002	Chemfix	TCLP	0.17	1.1	1.0	93	MSD
	005	Fly Ash	TCLP	0.63	1.6	1.0	97	MS
	005	Fly Ash	TCLP	0.63	1.6	1.0	97	MSD
Mean							85	
CV (%)							23	

(Continued)

TABLE 20. (Continued)

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Boron	002	Chemfix	TCLP	<0.600	1.13[a]	1.0	113	MS
	002	Chemfix	TCLP	<0.600	1.19[a]	1.0	119	MSD
	005	Fly Ash	TCLP	7.5	8.7	1.0	120	MS
	005	Fly Ash	TCLP	7.5	8.9	1.0	140	MSD
Mean							123	
CV (%)							10	
Cadmium	003	None	TCLP	0.009	0.051	0.050	84	MS
	003	None	TCLP	0.009	0.052	0.050	86	MSD
	007	None	TCLP	0.043	0.090	0.050	94	MS
	007	None	TCLP	0.043	0.084	0.050	82	MSD
	002	Chemfix	TCLP	0.007[a]	0.830	1.00	82	MS
	002	Chemifx	TCLP	0.007[a]	0.85	1.00	84	MSD
	005	Fly Ash	TCLP	0.090	0.93	1.00	84	MS
	005	Fly Ash	TCLP	0.090	0.92	1.00	83	MSD
Mean							85	
CV (%)							5	
Calcium	003	None	TCLP	570	650	100	80	MS
	003	None	TCLP	570	660	100	90	MSD
	007	None	TCLP	1320	1480	100	160	MS
	007	None	TCLP	1320	1410	100	90	MSD
Mean							105	
CV (%)							35	

(Continued)

TABLE 20. (Continued)

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Chromium	003	None	TCLP	<0.009	0.16	0.20	80	MS
	003	None	TCLP	<0.009	0.17	0.20	85	MSD
	007	None	TCLP	1.36	1.61	0.20	125	MS
	007	None	TCLP	1.36	1.51	0.20	75	MSD
	002	None	Ash	75	150	20	375	MS
	002	None	Ash	75	170	20	475	MSD
	002	Chemfix	Chemfix	0.080	0.91	1.00	83	MS
	002	Chemfix	Chemfix	0.080	0.94	1.00	86	MSD
	005	Fly Ash	Fly Ash	0.17	1.00	1.00	83	MS
	005	Fly Ash	Fly Ash	0.17	1.00	1.00	83	MSD
Mean							155	
CV (%)							93	
Copper	003	None	TCLP	<0.010	0.22	0.25	88	MS
	003	None	TCLP	<0.010	0.22	0.25	88	MSD
	007	None	TCLP	0.050	0.27	0.25	88	MS
	007	None	TCLP	0.050	0.25	0.25	80	MSD
	002	Chemfix	TCLP	0.032[a]	0.92	1.00	89	MS
	002	Chemfix	TCLP	0.032[a]	0.94	1.00	91	MSD
	005	Fly Ash	TCLP	0.31	1.2	1.00	89	MS
	005	Fly Ash	TCLP	0.31	1.2	1.00	89	MSD
Mean							88	
CV (%)							4	

(Continued)

TABLE 20. (Continued)

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Lead	001	None	TCLP	0.008[a]	0.046	0.050	76	MS
	001	None	TCLP	0.008[a]	0.048	0.050	80	MSD
	003	Chemfix	TCLP	0.004[a]	0.018	0.020	70	MS
	003	Chemfix	TCLP	0.004[a]	0.018	0.020	70	MSD
	007	Kilndust	TCLP	0.049	0.068	0.020	95	MS
	007	Kilndust	TCLP	0.049	0.072	0.020	115	MSD
Mean							84	
RSD (%)							21	
Mercury	001	None	TCLP	<0.0002	0.0011	0.0010	110	MS
	001	None	TCLP	<0.0002	0.0011	0.0010	110	MSD
	004	None	TCLP	<0.0002	0.0011	0.0010	110	MS
	004	None	TCLP	<0.0002	0.0011	0.0010	110	MSD
	001	None	Ash	0.21	0.85	0.25	256	MS
	001	None	Ash	0.21	0.50	0.25	116	MSD
	001	None	Ash	0.24	0.41	0.25	68	MS
	001	None	Ash	0.24	0.49	0.25	100	MSD
				<0.0002	0.004	0.004	100	MS
				<0.0002	0.0042	0.004	105	MSD
				0.0027	0.022	0.020	97	MS
				0.0027	0.023	0.020	102	MSD
Mean							115	
RSD (%)							40	

(Continued)

TABLE 20. (Continued)

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Nickel	003	None	TCLP	<0.020	0.32	0.40	80	MS
	003	None	TCLP	<0.020	0.32	0.40	80	MSD
	007	None	TCLP	0.25	0.60	0.40	88	MS
	007	None	TCLP	0.25	0.56	0.40	78	MSD
	002	None	Ash	118	140	50	44	MS
	002	None	Ash	118	960	50	1684	MSD
	002	Chemfix	TCLP	<0.02	0.84	1.00	84	MS
	002	Chemfix	TCLP	<0.02	0.85	1.00	85	MSD
	005	Fly Ash	TCLP	0.42	1.2	1.00	78	MS
	005	Fly Ash	TCLP	0.42	1.3	1.00	88	MSD
Mean							239	
CV (%)							213	
Selenium	001	None	TCLP	0.011	0.019	0.010	80	MS
	001	None	TCLP	0.011	0.021	0.010	100	MSD
	007	None	TCLP	<0.003	<0.003	0.010	0	MS
	007	None	TCLP	<0.003	<0.003	0.010	0	MSD
	002	None	Ash	1.60	2.70	1.00	110	MS
	002	None	Ash	1.60	2.60	0.96	104	MSD
	003	Chemfix	TCLP	<0.015	<0.015	0.020	0	MS
	003	Chemfix		<0.015	<0.015	0.020	0	MSD
	007	Kilndust		<0.015	<0.015	0.020	0	MS
	007	Kilndust		<0.015	<0.015	0.020	0	MSD
Mean							39	
RSD (%)							131	

(Continued)

TABLE 20. (Continued)

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Silver	003	None	TCLP	<0.009	0.055	0.050	110	MS
	003	None	TCLP	<0.009	0.059	0.050	118	MSD
	007	None	TCLP	0.018[a]	0.076	0.050	116	MS
	007	None	TCLP	0.018[a]	0.077	0.050	118	MSD
	002	None	Ash	21	95	5.0	1480	MS
	002	None	Ash	21	150	5.0	2580	MSD
	002	Chemfix	TCLP	0.019[a]	0.91	1.00	89	MS
	002	Chemfix	TCLP	0.019[a]	0.90	1.00	88	MSD
	005	Fly Ash	TCLP	0.024[a]	0.94	1.00	92	MS
	005	Fly Ash	TCLP	0.024[a]	0.92	1.00	90	MSD
Mean							488	
CV (%)							175	
Sodium	003	None	TCLP	1460	1520	100	60	MS
	003	None	TCLP	1460	1550	100	90	MSD
	007	None	TCLP	39	135	100	96	MS
	007	None	TCLP	39	128	100	89	MSD
	002	None	Ash	10700	11200	10000	5	MS
	002	None	Ash	10700	13000	10000	23	MSD
	002	Chemfix	TCLP	240	250	10	100	MS
	002	Chemfix	TCLP	240	250	10	100	MSD
	005	Fly Ash	TCLP	22	31	10	90	MS
	005	Fly Ash	TCLP	22	33	10	88	MSD
Mean							74	
CV (%)							46	

TABLE 20. (Continued)

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Silver	003	None	TCLP	<0.009	0.055	0.050	110	MS
	003	None	TCLP	<0.009	0.059	0.050	118	MSD
	007	None	TCLP	0.018[a]	0.076	0.050	116	MS
	007	None	TCLP	0.018[a]	0.077	0.050	118	MSD
	002	None	Ash	21	95	5.0	1480	MS
	002	None	Ash	21	150	5.0	2580	MSD
	002	Chemfix	TCLP	0.019[a]	0.91	1.00	89	MS
	002	Chemfix	TCLP	0.019[a]	0.90	1.00	88	MSD
	005	Fly Ash	TCLP	0.024[a]	0.94	1.00	92	MS
	005	Fly Ash	TCLP	0.024[a]	0.92	1.00	90	MSD
Mean							488	
CV (%)							175	
Sodium	003	None	TCLP	1460	1520	100	60	MS
	003	None	TCLP	1460	1550	100	90	MSD
	007	None	TCLP	39	135	100	96	MS
	007	None	TCLP	39	128	100	89	MSD
	002	None	Ash	10700	11200	10000	5	MS
	002	None	Ash	10700	13000	10000	23	MSD
	002	Chemfix	TCLP	240	250	10	100	MS
	002	Chemfix	TCLP	240	250	10	100	MSD
	005	Fly Ash	TCLP	22	31	10	90	MS
	005	Fly Ash	TCLP	22	33	10	88	MSD
Mean							74	
CV (%)							46	

TABLE 20. (Continued)

Analyte	Sample No.	Solidification Method	Sample Type	Sample Result (mg/L)	Spiked Sample Result (mg/L)	Spike Added (mg/L)	Recovery (%)	Type of Spike
Zinc	003	None	TCLP	<0.006	0.17	0.20	85	MS
	003	None	TCLP	<0.006	0.18	0.20	90	MSD
	007	None	TCLP	3.2	3.6	0.20	200	MS
	007	None	TCLP	3.2	3.4	0.20	100	MSD
	002	Chemfix	TCLP	0.015[a]	0.82	1.00	81	MS
	002	Chemfix	TCLP	0.015[a]	0.84	1.00	83	MSD
Mean							106	
CV (%)							43	

[a]Concentration is less than five times the minimum detection limit. Due to background noise at this level, the concentration listed is assumed to be +/-50% of the true value.

MS Matrix spike.
MSD Matrix spike duplicate.
CV Coefficient of variation (relative standard deviation).
RPD Relative percent difference.
NC Not calculable.

TABLE 21. SUMMARY OF PRECISION ESTIMATES FOR DUPLICATE ASH SAMPLE ANALYZED FOR ORGANICS[a]

Parameter	Mean Conc. (μg/Kg)	Relative Percent Difference
PHAs		
Napthalene	56	4.1
Acenaphthylene	<125	NC
Acenaphthene	7.4	29.7
Fluorene	15	6.9
Phenanthrene	43	4.7
Anthracene	<4	NC
Fluoranthene	30	46.7
Pytene	16	70.3
Benzo(a)anthracene	13	68.7
Chrysene	10	95.7
Benzo(e)pyrene	<6	NC
Benzo(b)fluorantahene	8.8	100
Benzo(k)fluoranthene	5.2	80.0
Benzo(a)pyrene	6.9	85.7
Dibenzo(a,h)anthracene	<3	NC
Benzo(g,h,i)perylene	9.3	72.7
PCBs-EPA Method 8080		
Aroclor 1211	<500	NC
Aroclor 1232	<500	NC
Aroclor 1242	<400	NC
Aroclor 1248	<250	NC
Aroclor 1254	<250	NC
Aroclor 1260	<250	NC
PCBs-EPA Method 680		
Monochlorobiphenyl	<2	NC
Dichlorobiphenyl	<2	NC
Trichlorobiphenyl	<2	NC
Tetrachlorobiphenyl	<2	NC
Hexachlorobiphenyl	<2	NC
Heptachlorobiphenyl	<2	NC
Octachlorobiphenyl	<2	NC
Nonachlorobiphenyl	<2	NC
Decachlorobiphenyl	<2	NC

(Continued)

TABLE 21. (Continued)

Parameter	Mean Conc. (μg/Kg)	Relative Percent Difference
CPs		
Phenol	450	13.3
2-Chlorophenol	<330	NC
2,4-Dichlorophenol	<330	NC
4-Chloro-3-m-phenol	<330	NC
2,4,6-Trichlorophenol	290	21.6
Pentachlorophenol	<660	NC
PCDDs/PCDFs		
2,3,7,8-TCDD	<.32	NC
Total TCDD	<.32	NC
Total TCDF	<.16	NC
Total PeCDD	<.25	NC
Total PeCDF	<.22	NC
Total HxCDD	<.48	NC
Total HxCDF	<.55	NC
Total HpCDD	<.65	NC
Total HpCDF	<.65	NC
Total OCDD	<.81	NC
Total OCDF	<.74	NC

[a]Duplicate sample of Dayton, OH combined ash.
PAH Polycyclic aromatic hydrocarbons.
PCB Polychlorinated biphenyls.
PC Phenols, chlorinated.
PCDD/PCDF Polychlorinated dibenzo-p-dioxins/polychlorinated dibenzofurans.

Polychlorinated Biphenyls--

PCBs were not detected by either EPA Method 8080 or EPA Method 680.

Chlorinated Phenols--

Results were reported for two chlorinated phenols in the duplicate ash samples at 450 and 290 μg/Kg. The RPD between results (13 and 21%) averaged 17 percent.

Polychlorinated Dibenzo-p-dioxins/Dibenzofurans--

Dioxins and furans were not detected.

4.2.2 Spiked Samples

Spiked sample results for organic analyses are summarized in Table 22. These results represent selected target analytes spiked into an ash sample, except for dioxins and furans, for which isotope-labeled surrogate compounds were spiked into every sample.

Polycyclic Aromatic Hydrocarbons--

Spike recoveries for PAHs were within expected limits ranging from 62 to 82% for five target compounds. The five target analytes were naphthalene, fluorene, anthracene, pyrene, and benzo(b)fluoranthene. The average spike recovery was 75 percent.

Polychlorinated Biphenyls--

The PCD spiking compound used in EPA Method 8080 was Aroclor 1254. Recovery was 50%, which is within the method acceptance criteria. The spiking compounds used in EPA Method 680 were ^{13}C-Monochlorobiphenyl, ^{13}C-Tetrachlorobiphenyl, ^{13}C-Octachlorobiphenyl and ^{13}C-Decachlorobiphenyl. The average spike recovery was 61 percent.

TABLE 22. SUMMARY OF SPIKED SAMPLE RESULTS FOR ORGANIC ANALYSES

Parameter	Recovery[a] (%)	Parameter	Mean Recovery[b] (%)	CV (%)
PAHs		Dioxins/Furans		
Naphthalene	71	TCDD	92	13
Fluorene	82	TCDF	95	7
Anthracene	62	PeCDD	86	19
Pyrene	80	PeCDF	84	19
Benzo(b)-fluoranthene	78	HxCDD	79	26
		HxCDF	56	29
		HpCDD	81	38
PCBs-EPA Method 8080		HpCDF	52	39
		OCDD	66	47
Aroclor 1254	50	OCDF	73	42
CPs		PCBs-EPA Method 680		
2-Chlorophenol	55	^{13}C-Monochlorobiphenyl	50	18
Pentachlorophenol	31	^{13}C-Tetrachlorobiphenyl	61	18
Phenol	90	^{13}C-Octachlorobiphenyl	69	9
o-Cresol	63	^{13}C-Decachlorobiphenyl	63	13
p-Cresol	77			
4-Nitrophenol	0			

[a]Recovery of target analyte spiked into one ash sample.
[b]Mean recovery of surrogate compounds spiked into eight samples.

Chlorinated Phenols--

The PC spikes were 2-chlorophenol and pentachlorophenol. Phenol, 4-nitrophenol, and o- and p-cresol spikes were also added. Recoveries for the chlorinated phenols, representing target analytes, were 55 and 31 percent. Recoveries for phenol and the cresols averaged 77 percent. No 4-nitrophenol was recovered.

Polychlorinated Dibenzo-p-dioxins/Dibenzofurans--

Surrogate spike recoveries for dioxins and furans are summarized in Table 23. The mean recovery for 10 spiking compounds ranged from 56 to 95%, all within the expected recovery range of 50 to 150 percent. The RPD for duplicate sample recoveries ranged from 0 to 26 percent. The coefficient of variation (CV) for surrogate recoveries in eight samples ranged from 7 to 47% for the 10 surrogate spiking compounds. Spike recoveries were lowest for sample number seven, which ranged from 0 to 82 percent. Recoveries in the other ashes were generally within the expected range.

4.3 PHYSICAL PARAMETERS

Duplicate ash samples were analyzed for pH and conductivity. Repeatability of results was within expected limits. The RPD was 0.5% for pH measurements and 1.8% for conductivity.

TABLE 23. MRIA METHOD 8280 SURROGATE RECOVERIES

Compound Class	Sample Number										
	1	2	3	4	5	5D	7	Blank	Mean	RPD[a]	CV[b]
TCDD	100	97	98	95	89	96	63	94	92	7.6	13.1
TCDF	96	96	96	94	95	107	82	96	95	11.9	7.1
PeCDD	94	98	95	83	90	94	47	88	86	4.3	19.1
PeCDF	89	95	94	81	87	91	46	90	84	4.5	19.0
HxCDD	81	92	98	79	82	88	30	79	79	7.1	26.4
HxCDF	45	77	73	44	57	57	29	66	56	0.0	28.8
HpCDD	88	96	109	94	80	99	10	73	81	21.2	38.0
HpCDF	44	71	80	47	53	56	11	55	52	5.5	39.3
OCDD	63	74	105	85	66	86	0	52	66	26.3	47.3
OCDF	71	91	111	87	67	84	8	63	73	22.5	41.7

[a]RDP - Relative percent difference for duplicate sample (5 and 5D) recoveries.
[b]CV - Coefficient of variation for all eight surrogate recoveries.

SECTION 5

SUMMARY AND RECOMMENDATIONS

Because organic compounds were either not detected or were found in low ppb levels in the ash samples, these compounds were not determined in the TCLP extracts. The most prevalent elements found in the ash samples were calcium, copper, lead, sodium, and zinc.

Permeability coefficients for solidified ash samples ranged from 1×10^{-5} to 6.6×10^{-6}. These results indicate that the solidified ash samples would be moderate to low in permeability as a disposed waste. Unconfined compressive strength (UCS) for the solidified ash samples ranged from 20.55 to 97.03 psi, indicating a high degree of variability in compressive strength.

Results of the analysis of TCLP extracts indicated that extractable metals were well below regulatory limits in all ash samples before and after the ash samples were solidified. Similarly, concentrations of metals in extracts from the SLT procedure were extremely low for all of the solidified ash samples.

Based on the results of this investigation, additional ash samples, known to be relatively high in metals and possibly organics, should be solidified and analyzed. Because of the extreme heterogeneity in metals concentrations in ash from MSW facilities, time-averaged samples should be obtained to provide a more accurate representation of ash characteristics.

APPENDIX A

PARTICLE SIZE DISTRIBUTION OF THE MRIA SAMPLES

GRAIN SIZE DISTRIBUTION

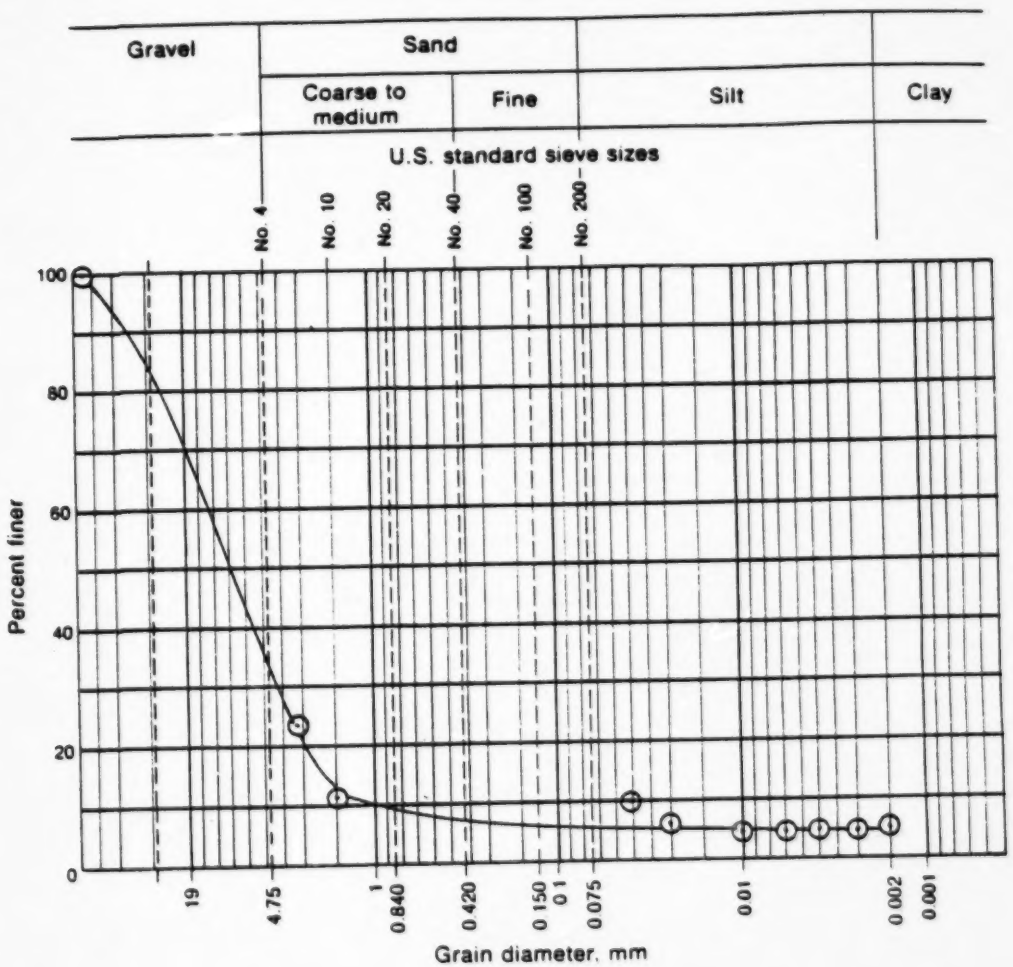
Data Sheet 6

Project MRIA - EPA ASH Job. No. COMBINED ASH - PINELLAS, FL.

Location of Project _____ Boring No. _____ Sample No. 001

Description of Soil _____ Depth of Sample _____

Tested By. _____ Date of Testing _____



Visual soil description Mean particle size - 7.0 mm

Soil classification:

_____ System _____

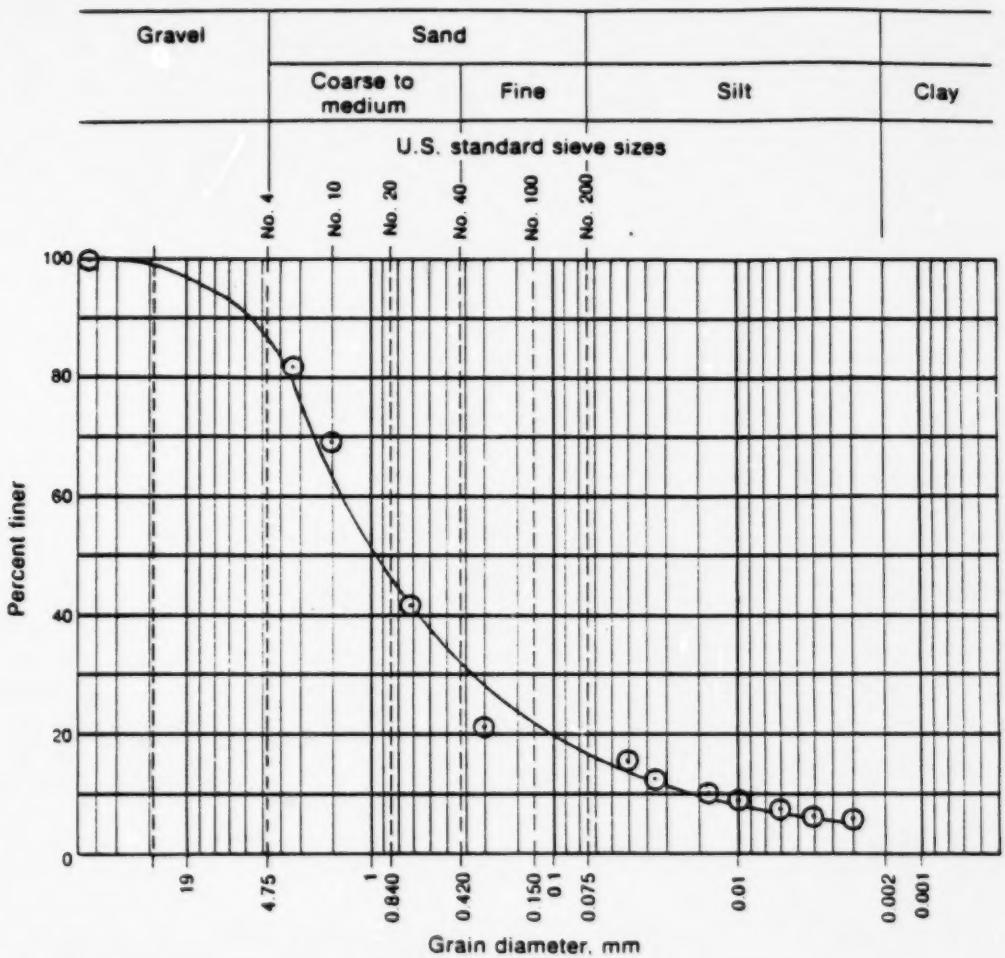
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project MRIA - EPA ASH Job. No. COMBINED ASH - WESTCHESTER, NY

Location of Project _____ Boring No. _____ Sample No. 002

Description of Soil _____ Depth of Sample _____

Tested By. _____ Date of Testing _____



Visual soil description Mean particle size - 0.35 mm

Soil classification:

_____ System _____

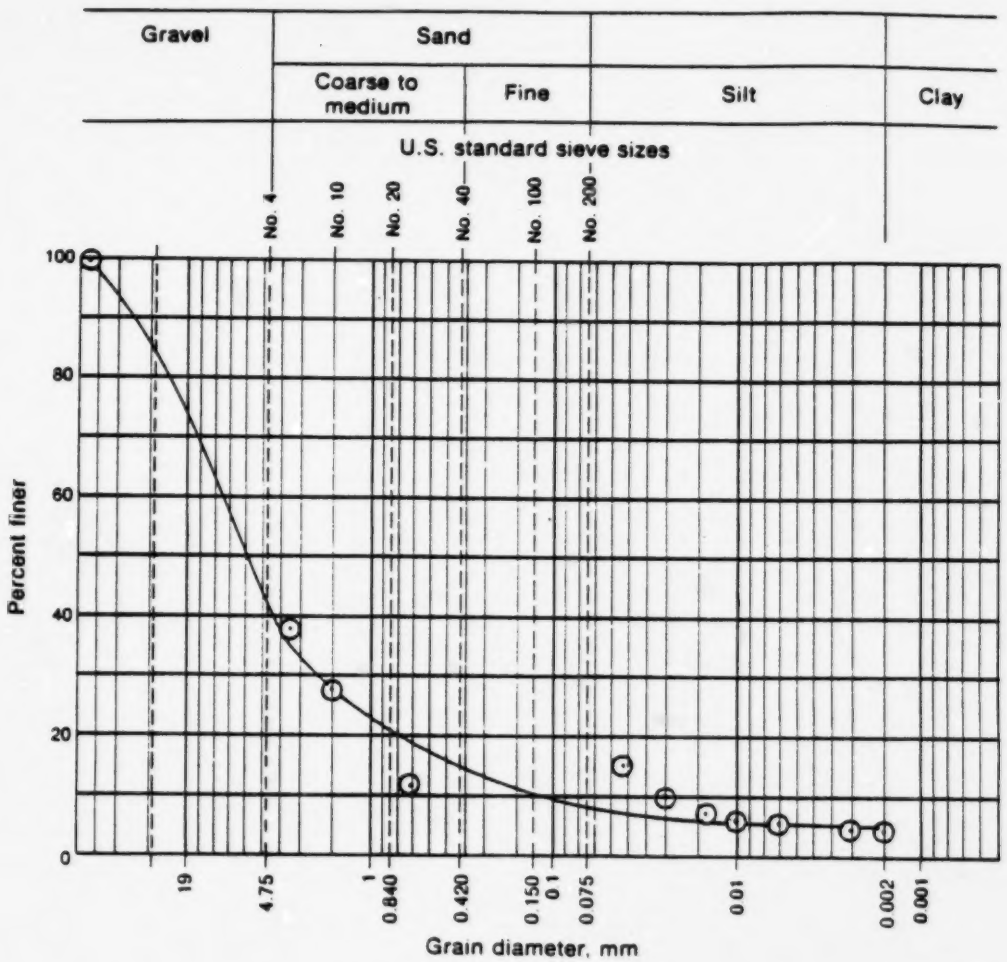
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project MRIA - EPA ASH Job. No. COMBINED ASH - PITTSFIELD, MA

Location of Project _____ Boring No. _____ Sample No. 004

Description of Soil _____ Depth of Sample _____

Tested By. _____ Date of Testing _____



Visual soil description Mean particle size - 6.0 mm

Soil classification:

_____ System _____

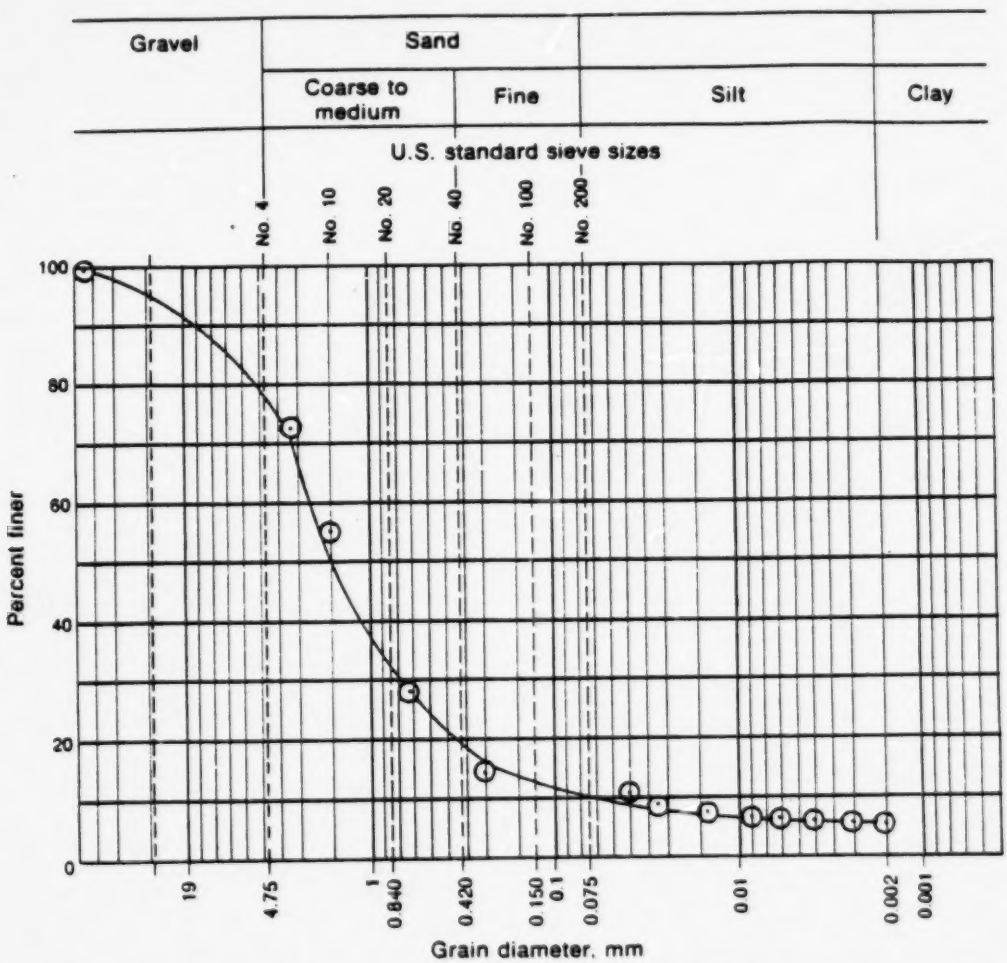
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project MRIA - EPA ASH Job. No. COMBINED ASH, - DAYTON, OH

Location of Project _____ Boring No. _____ Sample No. 005

Description of Soil _____ Depth of Sample _____

Tested By. _____ Date of Testing _____



Visual soil description Mean particle size - 2.0mm

Soil classification:

_____ System _____

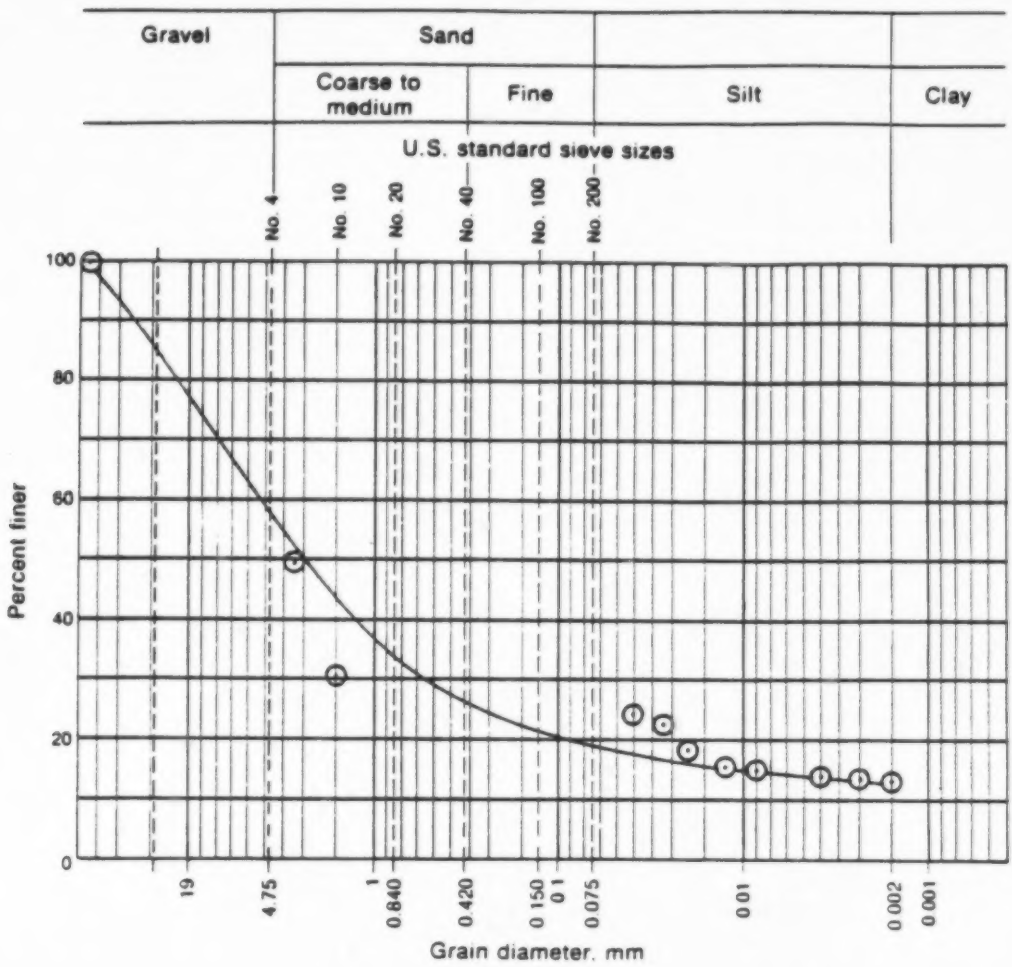
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project MRIA - EPA ASH Job. No. COMBINED ASH - MARION, OR

Location of Project _____ Boring No. _____ Sample No. 003

Description of Soil _____ Depth of Sample _____

Tested By. _____ Date of Testing _____



Visual soil description Mean particle size - 3.0 mm

Soil classification:

_____ System _____

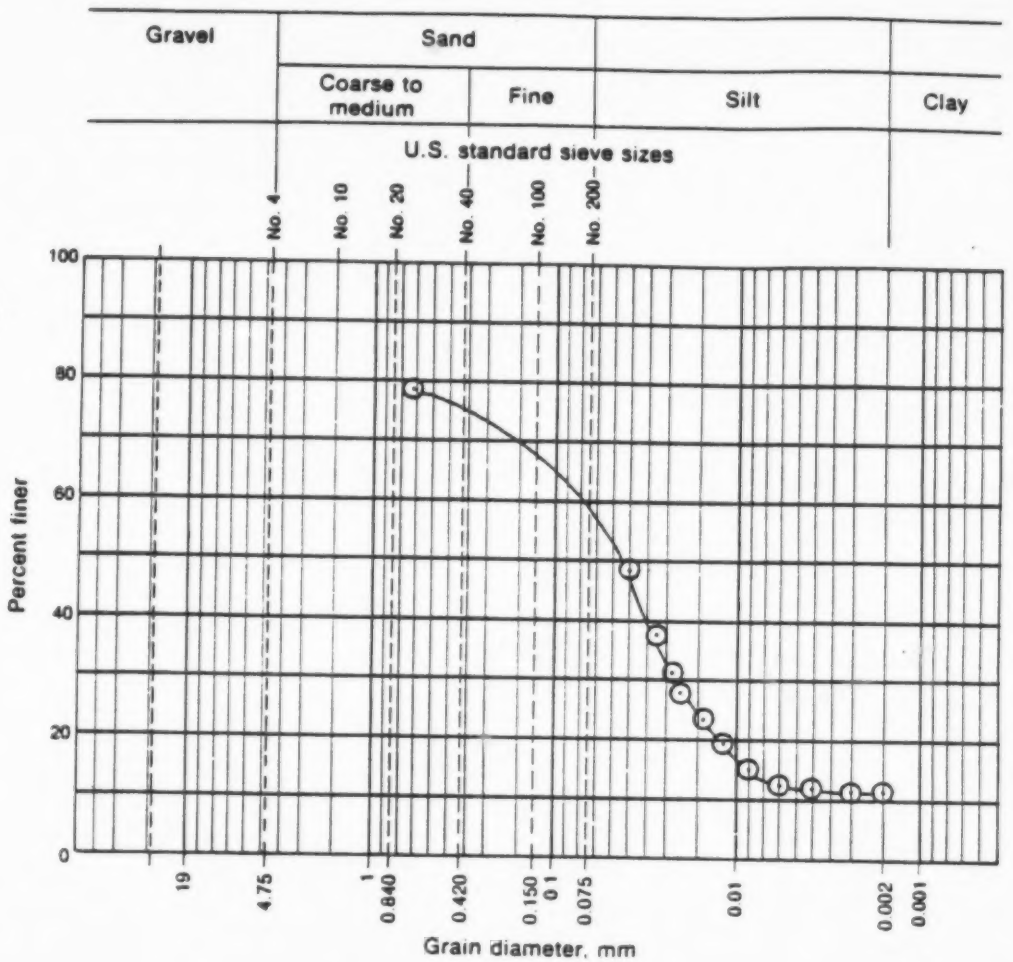
GRAIN SIZE DISTRIBUTION Data Sheet 6

Project MRIA - EPA ASH Job. No. FLY ASH - DAYTON, OH

Location of Project _____ Boring No. _____ Sample No. 007

Description of Soil _____ Depth of Sample _____

Tested By. _____ Date of Testing _____



Visual soil description Mean particle size - 0.055 mm

Soil classification:

_____ System _____

APPENDIX B

QC TEST RESULTS FOR ELEMENTAL ANALYSES

TABLE B-1. RESULTS OF QC TESTS FOR ELEMENTAL ANALYSES BY AAS

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
Arsenic	Control	0.046	0.046	100									
	Control	0.046	0.047	102									
	Control	0.046	0.046	100									
	Control	0.046	0.043	93									
	Control	0.046	0.044	96									
	MRIA-001 TCLP				<0.004	0.022	0.025	88	A				
	MRIA-001 TCLP				<0.004	0.032	0.040	80	MS				
	MRIA-001 TCLP				<0.004	0.031	0.040	78	MSD				
	MRIA-007 TCLP				0.100	0.120	0.040	50[d]	MS				
	MRIA-007 TCLP				0.100	0.120	0.040	50[d]	MSD				
	MRIA-001 TCLP									<0.004	<0.004	NC	M
	Control	0.040	0.034	85									
	Control	0.046	0.050	109									
	Control	0.046	0.047	102									
	Control	0.046	0.045	98									
	Control	0.046	0.046	100									
	MRIA-002 Ash				30	34	4.0	100	MS				
	MRIA-002 Ash				30	36	3.8	158[d]	MSD				
	MRIA-004 Ash				26	50	24	100	A				
	MRIA-001 Ash									15	15	0	A
	MRIA-001 Ash									15	14	7	M
	Control	0.040	0.037	93									
	Control	0.043	0.044	102									
	Control	0.043	0.040	93									
	Control	0.043	0.043	100									
	Control	0.043	0.042	98									
	Control	0.043	0.041	95									
	Control	0.043	0.041	95									
	Control	0.043	0.045	105									
	Control	0.043	0.039	91									
	Control	0.043	0.040	93									
	Ash-002 Chemfix,SLT-7									0.074	0.070	5.6	A
	Ash-003 D Chemfix,TCLP									0.011	0.011	0	M
	Ash-005 Kilndust,CSI,TCLP									<0.002	0.003	NC	M
	Ash-005 Flyash,CSI,TCLP									0.13	0.13	0	A
	Blank									<0.002	<0.002	NC	A
	Ash-007 Chemfix,SLT-14									0.054	0.056	3.6	A
	Blank				<0.002	0.018	0.020	90	P				
	Ash-001 Chemfix,SLT-7				0.012	0.034	0.025	88	A				
	Ash-003 Chemfix,TCLP				0.015	0.038	0.025	92	A				
	Ash-003 Chemfix,TCLP				0.015	0.031	0.020	80	MS				
	Ash-003 Chemfix,TCLP				0.015	0.031	0.020	80	MSD				

(Continued)

TABLE B-1. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	Ash-007 Kilndust,CSI,TCLP				0.004	0.028	0.025	96	A				
	Ash-007 Kilndust,CSI,TCLP				0.004	0.020	0.020	80	MS				
	Ash-007 Kilndust,CSI,TCLP				0.004	0.021	0.020	85	MSD				
	Ash-003 Chemfix,SLT-14				0.002	0.020	0.025	72	A				
	Ash-003 Chemfix,SLT-14				<0.008	0.10	0.10	100	A				
Mercury	Control	0.0040	0.0042	105									
	Control	0.0040	0.0042	105									
	Control	0.0040	0.0042	105									
	Control	0.0040	0.0042	105									
	Control	0.0040	0.0044	110									
	MRIA-001 TCLP				<0.0002	0.0011	0.0010	110	MS				
	MRIA-001 TCLP				<0.0002	0.0011	0.0010	110	MSD				
	MRIA-004 TCLP				<0.0002	0.0011	0.0010	110	MS				
	MRIA-004 TCLP				<0.0002	0.0011	0.0010	110	MSD				
	MRIA-007 TCLP									<0.0002	<0.0002	NC	M
	MRIA-001 Ash				0.21	0.85	0.25	256[d]	MS				
	MRIA-001 Ash				0.21	0.50	0.25	116[d]	MSD				
	MRIA-001 Ash				0.24	0.41	0.25	68[d]	MS				
	MRIA-001 Ash				0.24	0.49	0.25	100	MSD				
	MRIA-007 Ash									<0.05	<0.05	NC	M
	Control	0.0040	0.0038	95									
	Control	0.0040	0.0038	95									
	Control	0.0040	0.0044	110									
	Control	0.0040	0.0040	100									
	Control	0.0040	0.0042	105									
	Control	0.0040	0.0044	110									
	Control	0.0040	0.0042	105									
	Control	0.0040	0.0042	105									
	Control	0.0040	0.0042	105									
	Control	0.0040	0.0042	105									
	Ash-003 Chemfix,TCLP									0.0016	0.0016	0	M
	Blank									<0.0002	<0.0002	NC	M
	Blank				0.0002	0.0042	0.004	100	P				
	Ash-003 Chemfix,TCLP				0.0016	0.0058	0.004	105	P				
	QC				0.0017	0.0056	0.004	98	P				
	Blank				<0.0002	0.0040	0.004	100	MS				
	Blank				<0.0002	0.0042	0.004	105	MSD				
	QC				0.0027	0.022	0.020	97	MS				
	QC				0.0027	0.023	0.020	102	MSD				

(Continued)

TABLE B-1. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
Lead	Control	0.053	0.052	98									
	Control	0.053	0.057	108									
	Control	0.053	0.058	109									
	Control	0.053	0.058	109									
	MRIA-001 TCLP				0.008	0.046	0.050	76	MS				
	MRIA-001 TCLP				0.008	0.048	0.050	80	MSD				
	MRIA-002 TCLP				0.004	0.027	0.025	92	A				
	MRIA-007 TCLP				0.023	0.057	0.050	68[d]	P				
	MRIA-001 TCLP									0.002	0.012	NC	M
	MRIA-002 TCLP									0.006	0.006	NC	A
	Control	0.050	0.051	102									
	Control	0.053	0.056	106									
	Control	0.053	0.052	98									
	Control	0.053	0.049	92									
	Control	0.053	0.053	100									
	Control	0.053	0.053	100									
	MRIA-002 Ash				2870	2750	5.0	0[e]	MS				
	MRIA-003 Ash				1650	2820	1210	97	A				
	MRIA-001 Ash									860	588	38[f]	M
	MRIA-002 Ash									2870	2920	-2	A
	Control	0.050	0.045	90									
	Control	0.053	0.053	100									
	Control	0.053	0.052	98									
	Control	0.053	0.054	102									
	Control	0.053	0.054	102									
	Control	0.053	0.053	100									
	Control	0.053	0.056	106									
	Control	0.053	0.057	108									
	Control	0.053	0.058	109									
	Ash-003 D Chemfix,TCLP									0.002	0.002	NC	M
	Blank									0.008	0.009	NC	A
	Ash-007 Chemfix,SLT-14									0.035	0.036	2.8	A
	Ash-001 Chemfix,SLT-7									0.48	0.50	4.1	A
	Blank				<0.002	0.022	0.020	100	P				
	Ash-003 Chemfix,TCLP				0.004	0.025	0.025	84	A				
	Ash-003 Chemfix,TCLP				<0.008	0.092	0.010	92	A				
	Ash-003 Chemfix,TCLP				0.004	0.018	0.020	70[d]	MS				
	Ash-003 Chemfix,TCLP				0.004	0.018	0.020	70[d]	MSD				
	Ash-007 Kilndust,CSI,TCLP				0.049	0.068	0.020	95	MS				
	Ash-007 Kilndust,CSI,TCLP				0.049	0.072	0.020	115	MSD				

(Continued)

TABLE B-1. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	Ash-003 Chemfix,SLT-14				0.23	0.41	0.25	72	A				
	Ash-003 Chemfix,SLT-14				0.48	1.28	1.00	80	A				
	Ash-001 Chemfix,SLT-7				0.49	1.04	0.50	110	A				
Selenium	Control	0.050	0.050	100									
	Control	0.050	0.049	98									
	Control	0.050	0.048	96									
	Control	0.050	0.048	96									
	Control	0.050	0.048	96									
	MRIA-001 TCLP				0.011	0.019	0.010	80	MS				
	MRIA-001 TCLP				0.011	0.021	0.010	100	MSD				
	MRIA-002 TCLP				0.025	0.047	0.025	88	A				
	MRIA-002 TCLP				0.025	0.050	0.025	100	A				
	MRIA-007 TCLP				<0.003	<0.003	0.010	0[d]	MS				
	MRIA-007 TCLP				<0.003	<0.003	0.010	0[d]	MSD				
	TCLP Blank				0.006	0.027	0.025	84	A				
	TCLP Blank				0.006	0.029	0.025	92	A				
	MRIA-001 TCLP									0.018	0.017	5.7	M
	MRIA-002 TCLP									0.025	0.027	-7.7	A
	TCLP Blank									0.003	0.006	NC	A
	TCLP Blank									0.003	0.006	NC	A
	TCLP Blank									0.006	0.007	NC	A
	Control	0.050	0.051	102									
	Control	0.050	0.048	96									
	Control	0.050	0.046	92									
	Control	0.050	0.050	100									
	Control	0.050	0.046	92									
	Control	0.050	0.047	94									
	Control	0.050	0.050	100									
	Control	0.050	0.045	90									
	MRIA-001 Ash				<0.47	2.10	2.30	91	A				
	MRIA-002 Ash				1.60	2.70	1.00	110	MS				
	MRIA-002 Ash				1.60	2.60	0.96	104	MSD				
	MRIA-001 Ash									<0.47	<0.47	NC	A
	Control	0.050	0.055	110						<0.47	<0.49	NC	M
	Control	0.050	0.048	96									
	Control	0.050	0.051	102									
	Control	0.050	0.051	102									
	Control	0.050	0.053	106									

(Continued)

TABLE B-1. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	Control	0.050	0.052	104									
	Control	0.050	0.050	100									
	Control	0.050	0.049	98									
	Control	0.050	0.056	112									
	Control	0.050	0.050	100									
	Ash-003 D Chemfix,TCLP									<0.015	<0.015	NC	M
	Ash-007 Chemfix,SLT-14									<0.015	<0.015	NC	A
	Ash-002 Chemfix,SLT-7									0.014	0.016	13	A
	Blank				<0.003	0.021	0.020	105	P				
	Ash-003 Chemfix,TCLP				<0.015	0.105	0.125	84	A				
	Ash-003 Chemfix,TCLP				<0.060	0.62	0.50	124	A				
	Ash-003 Chemfix,TCLP				<0.015	<0.015	0.020	0[d]	MS				
	Ash-003 Chemfix,TCLP				<0.015	<0.015	0.020	0[d]	MSD				
	Ash-007 Kilndust,CSI,TCLP				<0.015	0.095	0.125	76	A				
	Ash-007 Kilndust,CSI,TCLP				<0.06	0.58	0.50	116	A				
	Ash-007 Kilndust,CSI,TCLP				<0.015	<0.015	0.020	0[d]	MS				
	Ash-007 Kilndust,CSI,TCLP				<0.015	<0.015	0.020	0[d]	MSD				
	Ash-003 Chemfix,SLT-14				<0.06	0.64	0.50	128	A				
	Ash-003 Chemfix,SLT-14				<0.24	2.40	2.00	120	A				
	Ash-001 Chemfix,SLT-7				<0.003	0.005	0.025	20	A				
	Ash-001 Chemfix,SLT-7				<0.03	0.32	0.25	128	A				

[a] %Recovery = (measured value/ true value)*100.
[b] %Recovery of spiked samples = ((spiked sample result - sample result)/spike added)*100.
[c] %Difference = [(sample result - duplicate result)/((sample result + duplicate result)/2)]*100.
[d] %Recovery was not within the control limit (75-125%R). This may indicate matrix interferences.
[e] Sample result is greater than four times the spike added. Thus, the spike added was masked by the sample concentration.
[f] The %Difference was out of the control limits, (80-100%D), for the matrix duplicate. This may indicate non-homogeneity of the sample.

A Analytical (bench) spike or duplicate.
P Predigestion spike not associated with matrix spike duplicate.
MS Matrix spike (digestion spike).
MSD Duplicate matrix spike (digestion spike).
M Matrix duplicate (digestion duplicate).
NC Not calculable due to a value less than five times the instrumental detection limit.

TABLE B-2. RESULTS OF QC TESTS FOR ELEMENTAL ANALYSES BY ICPES

		Control Samples			Spiked Samples					Duplicate Analyses			
Analyte	Sample ID	True Value (mg/L)	Measured Value (mg/L)	Percent Recovery[a]	Sample (mg/L)	Spiked Sample (mg/L)	Spike Added (mg/L)	Percent Recovery[b]	Type of Spike	Sample (mg/L)	Duplicate (mg/L)	Percent Difference[c]	Type of Duplicate
Barium	Control	10.0	10.0	100									
	Control	0.97	1.01	104									
	Control	5.00	5.21	104									
	Control	5.00	5.28	106									
	Control	5.00	5.25	105									
	Interference Check	0.49	0.48	98									
	Interference Check	0.49	0.49	100									
	MRIA-003 TCLP				0.21	1.95	2.00	87	MS				
	MRIA-003 TCLP				0.21	1.93	2.00	86	MDS				
	MRIA-007 TCLP				0.56	2.40	2.00	92	MS				
	MRIA-007 TCLP				0.56	2.30	2.00	87	MSD				
	MRIA-002 TCLP									0.15	0.15	0	M
	Control	10.0	10.0	100									
	Control	0.97	1.00	103									
	Control	5.00	5.15	103									
	Control	5.00	5.32	106									
	MRIA-002 Ash				520	580	200	30[d]	MS				
	MRIA-002 Ash				5..	700	200	90	MSD				
	MRIA-001 Ash									280	280	0	M
	Interference Check	0.49	0.47	96									
	Interference Check	0.49	0.49	100									
	Control	1.00	0.92	92									
	Control	2.00	2.08	104									
	Control	2.00	2.06	103									
	Control	2.00	2.07	104									
	Control	10.0	10.1	101									
	Control	0.97	1.03	106									
	Control	5.00	5.29	106									
	Control	5.00	5.20	104									
	Control	5.00	5.26	105									
	Interference Check	0.49	0.50	102									
	Interference Check	0.49	0.49	101									
	Ash-001 Chemfix,SLT-7									0.16	0.16	0	A
	Ash-001 Chemfix,SLT-7				0.16	2.05	2.00	97	A				
	Blank				<0.009	0.99	1.00	99	P				
	Ash-002 D Chemfix,TCLP				0.17	1.09	1.00	92	MS				
	Ash-002 D Chemfix,TCLP				0.17	1.10	1.00	93	MSD				
	Ash-005 Flyash,CSI,TCLP				0.63	1.60	1.00	97	MS				
	Ash-005 Flyash,CSI,TCLP				0.63	1.60	1.00	97	MSD				

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
Boron	Control	10.0	10.1	101									
	Control	0.99	1.03	104									
	Control	5.00	5.20	104									
	Control	5.00	5.39	108									
	Control	5.00	5.34	107									
	MRIA-003 TCLP									0.78	1.00	NC	M
	MRIA-003 TCLP									0.86	1.00	NC	M
	MRIA-007 TCLP									7.4	7.0	6	M
	MRIA-007 TCLP									7.0	7.0	0	M
	MRIA-002 TCLP									0.78	1.20	NC	M
	Control	10.0	9.80	98									
	Control	0.99	0.99	100									
	Control	5.00	5.15	103									
	Control	5.00	5.31	106									
	MRIA-002 Ash									87	87	0	M
	MRIA-001 Ash									<230	<230	NC	M
	Control	1.00	0.96	96									
	Control	2.00	2.02	101									
	Control	2.00	1.99	100									
	Control	2.00	2.06	103									
	Control	10.0	10.2	102									
	Control	0.99	0.98	99									
	Control	5.00	5.16	103									
	Control	5.00	5.15	103									
	Control	5.00	5.29	106									
	Ash-001 Chemfix,SLT-7									<0.600	<0.600	NC	A
	Ash-001 Chemfix,SLT-7				<0.600	2.24	2.00	112	A				
	Blank				<0.600	0.93	1.00	93	P				
	Ash-002 D Chemfix,TCLP				<0.600	1.13	1.00	113	MS				
	Ash-002 D Chemfix,TCLP				<0.600	1.19	1.00	119	MSD				
	Ash-005 Flyash,CSI,TCLP				7.50	8.70	1.00	120	MS				
	Ash-005 Flyash,CSI,TCLP				7.50	8.90	1.00	140[e]	SD				
Cadmium	Control	10.0	10.2	102									
	Control	0.94	0.94	100									
	Control	5.00	5.29	106									
	Control	5.00	5.43	109									
	Control	5.00	5.37	107									
	Interference Check	0.90	0.92	102									
	Interference Check	0.90	0.92	102									

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	MRIA-003 TCLP				0.009	0.051	0.050	84	MS				
	MRIA-003 TCLP				0.009	0.052	0.050	86	MSD				
	MRIA-007 TCLP				0.043	0.090	0.050	94	MS				
	MRIA-007 TCLP				0.043	0.084	0.050	82	MSD				
	MRIA-002 TCLP									0.006	0.007	NC	M
	Control	10.0	10.0	100									
	Control	0.94	0.92	98									
	Control	5.00	5.19	104									
	Control	5.00	5.44	109									
	MRIA-002 Ash				82	150	5.0	1360[e]	MS				
	MRIA-002 Ash				82	180	5.0	1960[e]	MSD				
	MRIA-001 Ash									9.2	16	-54[f]	M
	Interference Check	0.90	0.86	96									
	Interference Check	0.90	0.91	101									
	Control	1.00	0.89	89									
	Control	2.00	1.98	99									
	Control	2.00	1.94	97									
	Control	2.00	1.96	98									
	Control	10.0	10.1	101									
	Control	0.94	0.92	98									
	Control	5.00	5.27	105									
	Control	5.00	5.20	104									
	Control	5.00	5.23	105									
	Interference Check	0.90	0.90	99									
	Interference Check	0.90	0.91	101									
	Ash-001 Chemfix,SLT-7									<0.003	<0.003	NC	A
	Ash-001 Chemfix,SLT-7				<0.003	1.81	2.00	91	A				
	Blank				<0.003	0.96	1.00	96	P				
	Ash-002 D Chemfix,TCLP				0.007	0.83	1.00	82	MS				
	Ash-002 D Chemfix,TCLP				0.007	0.85	1.00	84	MSD				
	Ash-005 Flyash,CSI,TCLP				0.090	0.93	1.00	84	MS				
	Ash-005 Flyash,CSI,TCLP				0.090	0.92	1.00	83	MSD				
Calcium	Control	300	303	101									
	Control	1.00	1.11	111									
	Control	150	146	97									
	Control	150	148	99									
	Control	150	150	100									
	MRIA-003 TCLP				570	650	100	80	MS				
	MRIA-003 TCLP				570	60	100	90	MSD				

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	MRIA-007 TCLP				1320	1480	100	160[d]	MS				
	MRIA-007 TCLP				1320	1410	100	90	MSD				
	MRIA-002 TCLP									550	560	-2	M
	Control	300	298	99									
	Control	1.00	1.05	105									
	Control	150	145	97									
	Control	150	149	99									
	MRIA-002 Ash				49300	46000	10000	0[e]	MS				
	MRIA-002 Ash				49300	50300	10000	10[e]	MSD				
	MRIA-001 Ash									42900	54700	-24[f]	M
	Control	10.0	9.2	92									
	Control	20.0	20.3	102									
	Control	20.0	19.9	100									
	Control	20.0	19.9	100									
	Control	300	298	99									
	Control	41	41	100									
	Control	150	140	93									
	Control	150	141	94									
	Control	150	142	95									
	Ash-001 Chemfix,SLT-7									41	41	0	A
	Ash-001 Chemfix,SLT-7				41	62	20	103	A				
	Blank				<0.08	9.5	10	95	P				
	Ash-002 D Chemfix,TCLP				1372	1374	10	20[e]	MS				
	Ash-002 D Chemfix,TCLP				1370	1380	10	100	MSD				
	Ash-002 D Chemfix,TCLP				1430	1460	10	300[e]	MS				
	Ash-002 D Chemfix,TCLP				1430	1460	10	300[e]	MSD				
	Ash-005 Flyash,CSI,TCLP				1680	1730	10	500[e]	MS				
	Ash-005 Flyash,CSI,TCLP				1680	2170	10	4900[e]	MSD				
Chromium	Control	10.0	10.1	101									
	Control	1.03	1.02	99									
	Control	5.00	5.11	102									
	Control	5.00	5.23	105									
	Control	5.00	5.19	104									
	Interference Check	0.91	0.96	105									
	Interference Check	0.91	0.94	103									
	MRIA-003 TCLP				<0.009	0.16	0.20	80	MS				
	MRIA-003 TCLP				<0.009	0.17	0.20	85	MSD				
	MRIA-007 TCLP				1.36	1.61	0.20	125	MS				
	MRIA-007 TCLP				1.36	1.51	0.20	75	MSD				

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	MRIA-002 TCLP									<0.009	<0.009	NC	M
	Control	10.0	9.9	99									
	Control	1.03	0.98	95									
	Control	5.00	5.01	100									
	Control	5.00	5.22	104									
	MRIA-002 Ash				75	150	20	375[d]	MS				
	MRIA-002 Ash				75	170	20	475[d]	MSD				
	MRIA-001 Ash									55	38	37[f]	M
	Interference Check	0.91	0.89	98									
	Interference Check	0.91	0.93	102									
	Control	1.00	0.91	91									
	Control	2.00	2.04	102									
	Control	2.00	2.01	101									
	Control	2.00	2.03	102									
	Control	10.0	10.1	101									
	Control	1.03	1.00	97									
	Control	5.00	5.12	102									
	Control	5.00	5.07	101									
	Control	5.00	5.10	102									
	Interference Check	0.91	0.93	102									
	Ash-001 Chemfix,SLT-7									0.20	0.19	5.1	A
	Ash-001 Chemfix,SLT-7				0.20	2.12	2.00	96	A				
	Blank				<0.009	0.94	1.00	94	P				
	Ash-002 D Chemfix,TCLP				0.08	0.91	1.00	83	MS				
	Ash-002 D Chemfix,TCLP				0.08	0.94	1.00	86	MSD				
	Ash-005 Flyash,CSI,TCLP				0.17	1.00	1.00	83	MS				
	Ash-005 Flyash,CSI,TCLP				0.17	1.00	1.00	83	MSD				
Copper	Control	10.0	10.0	100									
	Control	1.03	0.99	96									
	Control	5.00	5.08	102									
	Control	5.00	5.14	103									
	Control	5.00	5.10	102									
	Interference Check	0.46	0.49	107									
	Interference Check	0.46	0.48	104									
	MRIA-003 TCLP				<0.010	0.22	0.25	88	MS				
	MRIA-003 TCLP				<0.010	0.22	0.25	88	MSD				
	MRIA-007 TCLP				0.050	0.27	0.25	88	MS				
	MRIA-007 TCLP				0.050	0.25	0.25	80	MSD				
	MRIA-002 TCLP									<0.010	<0.010	NC	M

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	Control	10.0	10.0	100									
	Control	1.03	0.98	95									
	Control	5.00	5.00	100									
	Control	5.00	5.15	103									
	MRIA-002 Ash				3470	1800	25	0	MS				
	MRIA-002 Ash				3470	1760	25	0	MSD				
	MRIA-001 Ash									1640	470	111[f]	M
	Interference Check	0.46	0.46	100									
	Interference Check	0.46	0.48	104									
	Control	1.00	0.91	91									
	Control	2.00	2.04	102									
	Control	2.00	2.02	101									
	Control	2.00	2.03	102									
	Control	10.0	10.1	101									
	Control	1.03	1.01	98									
	Control	5.00	5.16	103									
	Control	5.00	5.07	101									
	Control	5.00	5.14	103									
	Interference Check	0.45	0.49	108									
	Ash-001 Chemfix,SLT-7									0.27	0.27	0	A
	Ash-001 Chemfix,SLT-7				0.27	2.10	2.00	92	A				
	Blank				0.011	0.94	1.00	94	P				
	Ash-002 D Chemfix,TCLP				0.032	0.92	1.00	89	MS				
	Ash-002 D Chemfix,TCLP				0.032	0.94	1.00	91	MSD				
	Ash-005 Flyash,CSI,TCLP				0.31	1.20	1.00	89	MS				
	Ash-005 Flyash,CSI,TCLP				0.31	1.20	1.00	89	MSD				
Nickel	Control	10.0	10.1	101									
	Control	1.02	1.01	99									
	Control	5.00	5.08	102									
	Control	5.00	5.22	104									
	Control	5.00	5.17	103									
	Interference Check	0.91	0.93	102									
	Interference Check	0.91	0.92	101									
	MRIA-003 TCLP				<0.020	0.32	0.40	80	MS				
	MRIA-003 TCLP				<0.020	0.32	0.40	80	MSD				
	MRIA-007 TCLP				0.25	0.60	0.40	87	MS				
	MRIA-007 TCLP				0.25	0.56	0.40	78	MSD				
	MRIA-002 TCLP									<0.020	<0.020	NC	M
	Control	10.0	9.9	99									

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	Control	1.02	0.98	96									
	Control	5.00	4.97	99									
	Control	5.00	5.23	105									
	MRIA-002 Ash				118	140	50	44[d]	MS				
	MRIA-002 Ash				118	960	50	1684[d]	MSD				
	MRIA-001 Ash									55	17	NC	M
	Interference Check	0.91	0.88	97									
	Interference Check	0.91	0.93	102									
	Control	1.00	0.88	88									
	Control	2.00	2.00	100									
	Control	2.00	1.96	98									
	Control	2.00	1.99	100									
	Control	10.0	10.1	101									
	Control	1.02	1.01	99									
	Control	5.00	5.07	101									
	Control	5.00	5.02	100									
	Control	5.00	5.04	101									
	Interference Check	0.91	0.91	100									
	Ash-001 Chemfix,SLT-7									<0.020	0.030	NC	A
	Ash-001 Chemfix,SLT-7				<0.020	1.84	2.00	92	A				
	Blank				<0.020	0.93	1.00	93	P				
	Ash-002 D Chemfix,TCLP				<0.020	0.84	1.00	84	MS				
	Ash-002 D Chemfix,TCLP				<0.020	0.85	1.00	85	MSD				
	Ash-005 Flyash,CSI,TCLP				0.42	1.20	1.00	78	MS				
	Ash-005 Flyash,CSI,TCLP				0.42	1.30	1.00	88	MSD				
Silver	Control	10.0	10.5	105									
	Control	0.99	1.03	104									
	Control	5.00	5.05	101									
	Control	5.00	5.06	101									
	Control	5.00	5.05	101									
	Interference Check	1.06	1.07	101									
	Interference Check	1.06	1.05	99									
	MRIA-003 TCLP				<0.009	0.055	0.050	110	MS				
	MRIA-003 TCLP				<0.009	0.059	0.050	118	MSD				
	MRIA-007 TCLP				0.018	0.076	0.050	116	MS				
	MRIA-007 TCLP				0.018	0.077	0.050	118	MSD				
	MRIA-002 TCLP									<0.009	<0.009	NC	M
	Control	10.0	10.4	104									
	Control	0.99	1.04	105									

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	Control	5.00	5.14	103									
	Control	5.00	5.16	103									
	MRIA-002 Ash				21	95	5.0	1480[e]	MS				
	MRIA-002 Ash				21	150	5.0	2580[e]	MSD				
	MRIA-001 Ash									5.8	4.4	27	M
	Interference Check	1.06	1.04	98									
	Interference Check	1.06	1.06	100									
	Control	1.00	0.89	89									
	Control	2.00	2.06	103									
	Control	2.00	2.03	102									
	Control	2.00	2.04	102									
	Control	10.0	10.0	100									
	Control	0.99	0.97	98									
	Control	5.00	4.77	95									
	Control	5.00	4.76	95									
	Control	5.00	4.72	94									
	Interference Check	1.07	0.98	92									
	Ash-001 Chemfix,SLT-7									0.019	0.023	NC	A
	Ash-001 Chemfix,SLT-7				0.021	1.96	2.00	97	A				
	Blank				<0.009	0.91	1.00	91	P				
	Ash-002 D Chemfix,TCLP				0.019	0.91	1.00	89	MS				
	Ash-002 D Chemfix,TCLP				0.019	0.90	1.00	88	MSD				
	Ash-005 Flyash,CSI,TCLP				0.024	0.94	1.00	92	MS				
	Ash-005 Flyash,CSI,TCLP				0.024	0.92	1.00	90	MSD				
Sodium	Control	300	300	100									
	Control	47	51	109									
	Control	150	157	105									
	Control	150	155	103									
	Control	150	154	103									
	MRIA-003 TCLP				1460	1520	100	60[d]	MS				
	MRIA-003 TCLP				1460	1550	100	90	MSD				
	MRIA-007 TCLP				39	135	100	96	MS				
	MRIA-007 TCLP				39	128	100	89	MSD				
	MRIA-002 TCLP									1300	1270	2	M
	Control	300	301	100									
	Control	46.5	51.4	111									
	Control	150	158	105									
	Control	150	162	108									
	MRIA-002 Ash				10700	11200	10000	5[d]	MS				

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	MRIA-002 Ash				10700	13000	10000	23[d]	MSD				
	MRIA-001 Ash									3030	2640	14	M
	Control	10.0	9.7	97									
	Control	20.0	20.6	103									
	Control	20.0	20.9	105									
	Control	20.0	20.5	103									
	Control	300	298	99									
	Control	47	50	106									
	Control	150	149	99									
	Control	150	152	101									
	Control	150	153	102									
	Ash-001 Chemfix,SLT-7									1700	1700	0	A
	Ash-001 Chemfix,SLT-7				1700	1900	120	167[e]	A				
	Blank				<0.08	10.1	10	101	P				
	Ash-002 D Chemfix,TCLP				240	250	10	100	MS				
	Ash-002 D Chemfix,TCLP				240	250	10	100	MSD				
	Ash-005 Flyash,CSI,TCLP				22	31	10	90	MS				
	Ash-005 Flyash,CSI,TCLP				22	33	10	88	MSD				
Zinc	Control	10.0	10.2	102									
	Control	1.01	1.03	102									
	Control	5.00	5.34	107									
	Control	5.00	5.12	102									
	Control	5.00	5.46	109									
	Interference Check	1.04	1.07	103									
	Interference Check	1.04	1.05	101									
	MRIA-003 TCLP				<0.006	0.17	0.20	85	MS				
	MRIA-003 TCLP				<0.006	0.18	0.20	90	MSD				
	MRIA-007 TCLP				3.20	3.60	0.20	200[d]	MS				
	MRIA-007 TCLP				3.20	3.40	0.20	100	MSD				
	MRIA-002 TCLP									<0.006	<0.006	NC	M
	Control	10.0	9.9	99									
	Control	1.01	1.00	99									
	Control	5.00	5.20	104									
	Control	5.00	5.48	110									
	MRIA-002 Ash				6550	5600	50	-1900[d]	MS				
	MRIA-002 Ash				6550	10100	50	7100[d]	MSD				
	MRIA-001 Ash									1500	1130	28[f]	M
	Interference Check	1.04	1.08	104									
	Interference Check	1.04	1.10	106									

(Continued)

TABLE B-2. (Continued)

Analyte	Sample ID	Control Samples: True Value (mg/L)	Control Samples: Measured Value (mg/L)	Control Samples: Percent Recovery[a]	Spiked Samples: Sample (mg/L)	Spiked Samples: Spiked Sample (mg/L)	Spiked Samples: Spike Added (mg/L)	Spiked Samples: Percent Recovery[b]	Spiked Samples: Type of Spike	Duplicate Analyses: Sample (mg/L)	Duplicate Analyses: Duplicate (mg/L)	Duplicate Analyses: Percent Difference[c]	Duplicate Analyses: Type of Duplicate
	Control	1.00	0.87	87									
	Control	2.00	1.99	100									
	Control	2.00	1.96	98									
	Control	2.00	1.98	99									
	Control	10.0	10.1	101									
	Control	1.01	1.02	101									
	Control	5.00	5.29	106									
	Control	5.00	5.24	105									
	Control	5.00	5.27	105									
	Interference Check	1.04	1.09	105									
	Ash-001 Chemfix,SLT-7									0.050	0.050	0	A
	Ash-001 Chemfix,SLT-7				0.05	1.91	2.00	93	A				
	Blank				<0.006	0.95	1.00	95	P				
	Ash-002 D Chemfix,TCLP				0.015	0.82	1.00	81	MS				
	Ash-002 D Chemfix,TCLP				0.015	0.84	1.00	83	MSD				
	Ash-005 Flyash,CSI,TCLP				59	61	1.00	20[e]	MS				
	Ash-005 Flyash,CSI,TCLP				59	61	1.00	20[e]	MSD				

[a] %Recovery = (measured value/ true value)*100.
[b] %Recovery of spiked samples = ((spiked sample result - sample result)/spike added)*100.
[c] %Difference = [(sample result - duplicate result)/((sample result + duplicate result)/2)]*100.
[d] %Recovery was not within the control limit (75-125%R). This may indicate matrix interferences.
[e] The %Difference was out of the control limits, (80-100%D), for the matrix duplicate. This may indicate non-homogeneity of the sample.
[f] Sample result is greater than four times the spike added. Thus, the spike added was masked by the sample concentration.

P Predigestion spike not associated with matrix spike duplicates.
MS Matrix spike (digestion spike).
MSD Duplicate matrix spike (digestion spike).
A Analytical (bench) spike or duplicate.
M Matrix duplicate (digestion duplicate).
NC Not calculable due to a value less than five times the instrumental detection limit.

APPENDIX C

PCB RESULTS BY EPA METHOD 680

TABLE C-1. EPA METHOD 680 POLYCHLORINATEDBIPHENYL ANALYSES OF THE EPA ASH SAMPLE

Compound	Method Detection Limit (ng/g)	Laboratory Blank (ng/g)	Marion, OR Combined Ash Ash-003 (ng/g)	Pittsfield, MA Combined Ash Ash-004 (ng/g)	Dayton, OH Combined Ash Ash-005 ng/g)	Dayton, OH Fly Ash Ash-007 (ng/g)
Monochlorobiphenyl	2	ND	ND	ND	ND	ND
Dichlorobiphenyl	2	ND	ND	ND	ND	ND
Trichlorobiphenyl	2	ND	ND	ND	ND	ND
Tetrachlorobiphenyl	2	ND	ND	ND	ND	ND
Hexachlorobiphenyl	2	ND	ND	ND	ND	ND
Heptachlorobiphenyl	2	ND	ND	ND	ND	ND
Octachlorobiphenyl	2	ND	ND	ND	ND	ND
Nonachlorobiphenyl	2	ND	ND	ND	ND	ND
Decachlorobiphenyl	2	ND	ND	ND	ND	ND

ND = Not detected.